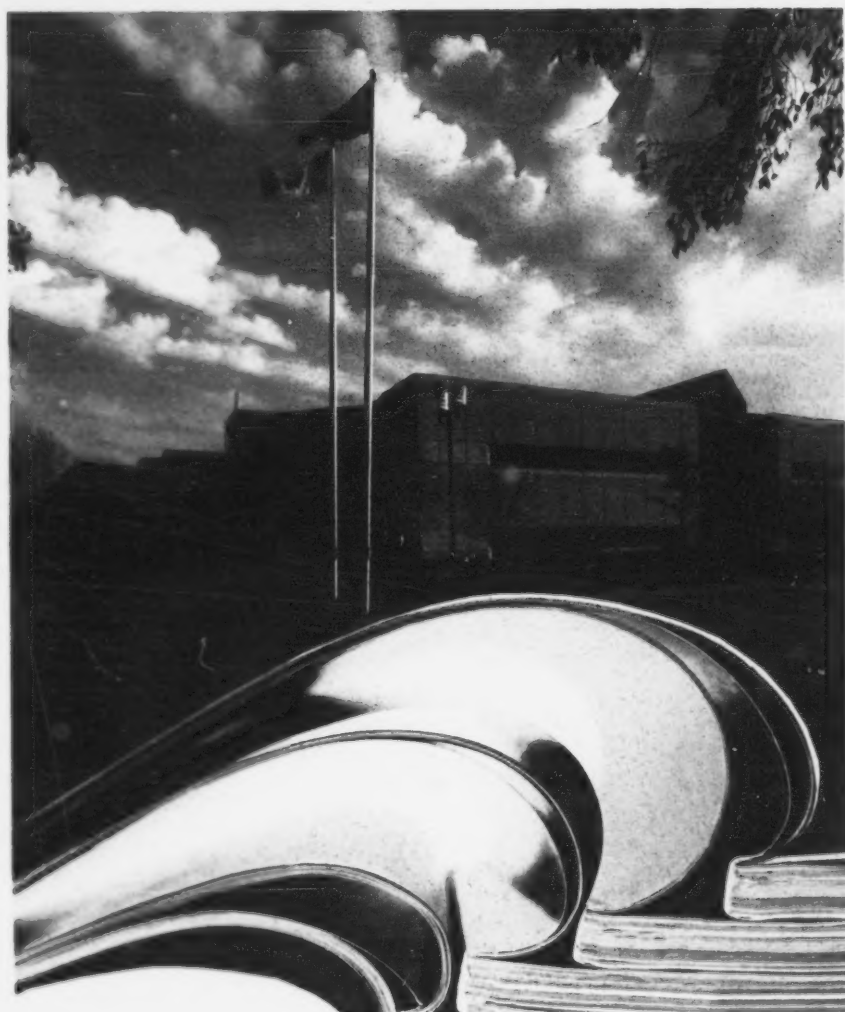
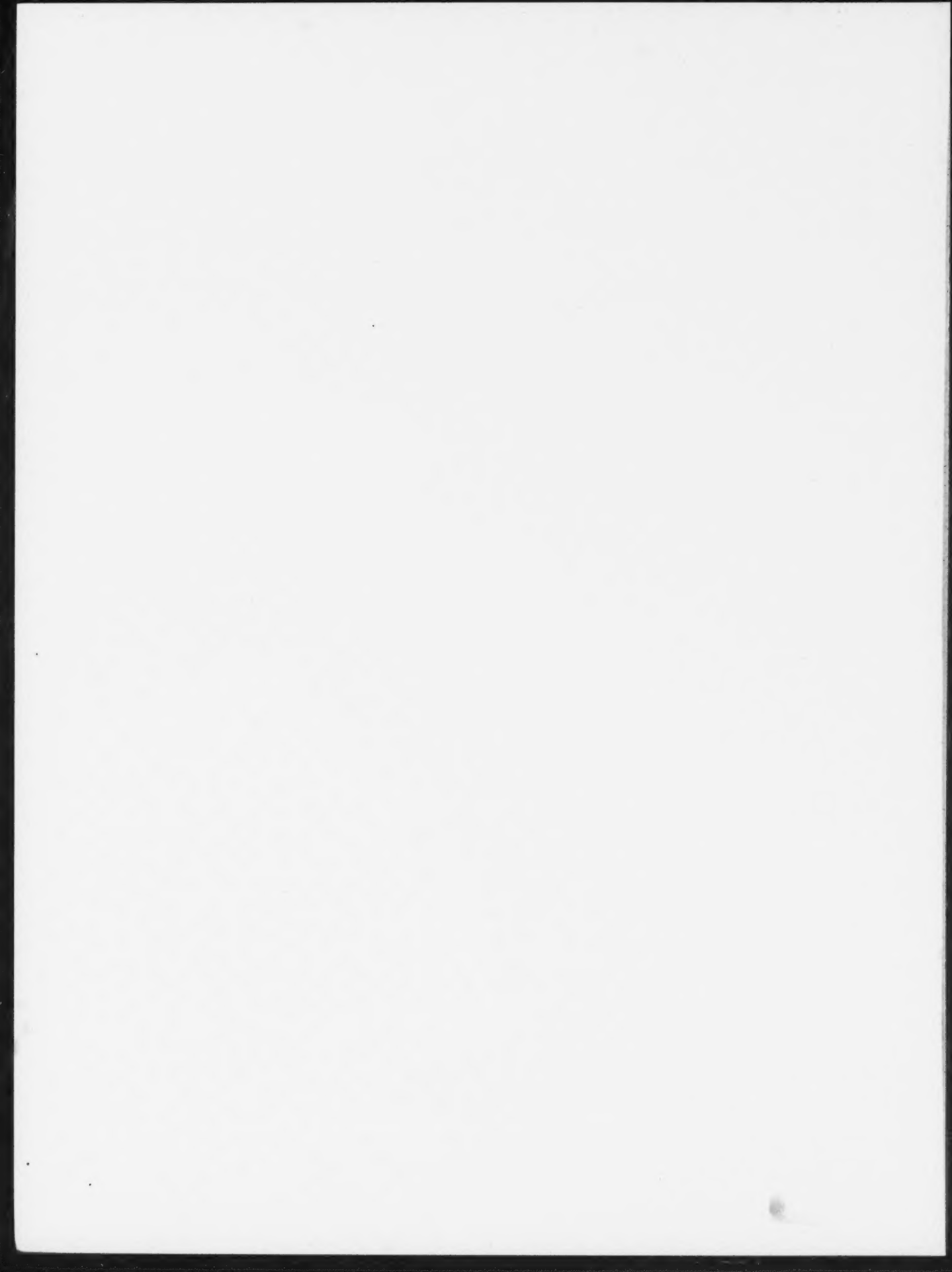


Ontario Forest Research Institute Publications 2006-2010: A Bibliography with Abstracts





Ontario Forest Research Institute Publications 2006-2010: A Bibliography with Abstracts

Compiled by
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This paper contains recycled materials.

Abstract

This bibliography includes a list and descriptions of the content of publications written or co-authored by staff of the Ontario Ministry of Natural Resources' Ontario Forest Research Institute between 2006 and 2010. During this five-year period, over 150 publications were produced by the institute's 14 research scientists, including a book, 83 journal articles, 31 reports, 10 technical notes, 5 newsletters, and 11 papers/summaries in conference/workshop proceedings. The overall focus of the publications is forest resource management-related research and practice. Topical areas and scales of investigation are diverse and include natural disturbance regimes and landscape dynamics; carbon budgets and effects of climate change on forests; and silviculture studies on site preparation, tree improvement, vegetation management, growth and yield, disease management, and harvesting in conifer, mixedwood, and hardwood forests. Author and subject indexes are provided.

Resumé

Cette bibliographie comprend une liste et une description du contenu des publications de 2006 à 2010 d'auteurs (ou de co-auteurs) faisant partie du personnel de l'Institut de recherche forestière de l'Ontario du ministère des Richesses naturelles. Au cours de cette période de cinq ans, plus de 150 publications ont été produites par les 14 chercheurs scientifiques, dont un livre, 83 articles, 31 rapports, 10 notes techniques, 5 bulletins d'information et 11 articles/résumés dans les comptes rendus de conférences/ateliers. Les publications portent généralement sur la recherche et la pratique reliées à la gestion des ressources forestières. Les thèmes abordés et les sujets de recherche sont variés et comprennent les régimes de perturbation naturelle et la dynamique du paysage; le bilan du carbone et les effets du changement climatique sur les forêts; et les études de silviculture sur la préparation de sites, l'amélioration des arbres, la gestion de la végétation, la croissance et le rendement, la lutte contre les maladies et la récolte dans les forêts de conifères, les forêts mixtes et les forêts de feuillus. Les noms des auteurs et les indexes par sujet sont aussi fournis.

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Introduction

This bibliography includes a list and brief descriptions of the content of books, book chapters, journal articles, research reports, information papers, technical notes, symposium proceedings, newsletter articles, papers in conference proceedings, and other reports written or co-authored by OFRI staff between 2006 and 2010.

Topics covered are diverse but all fall within an overall goal of understanding the effects of disturbance and change on forest ecosystems across Ontario to improve forest policy and practice. Some examples are understanding natural disturbance regimes and landscape dynamics, estimating carbon budgets and effects of climate change on forests and peatlands, understanding the effects of silvicultural treatments on forest ecosystems.

Publications are listed alphabetically by first author. Only OFRI authors are included in the author index (Appendix I). A subject index is also provided (Appendix II). Composite lists of the provincial report series to which OFRI staff contribute are provided by report number – Forest Research Reports (Appendix III), Forest Research Information Papers (Appendix IV), Forest Research Notes (Appendix V), Climate Change Research Reports (Appendix VI), Climate Change Information Notes (Appendix VII), and Science Development and Transfer Series Reports (Appendix VIII), with OFRI author names in bold.

The number of various types of publications produced by OFRI authors between 2006 and 2010 are summarized in Table 1.

Table 1. Summary of types of publications produced by OFRI authors between 2006 and 2010.

Publication	2006	2007	2008	2009	2010
Book	1	-	-	-	-
Research article	15	11	27	17	15
Book chapter	4	-	-	-	-
Report	7	7	12	5	4
Paper/summary in conference/workshop proceedings	6	1	1	-	-
Technical note	3	1	1	3	2
Newsletter	1	1	1	1	1
Other (e.g., magazine article, internal report)	2	3	1	2	-
Total	39	24	40	28	22

Bibliography

- Baker, J.A., F.W. Bell and A. Stinson. 2008. **Ontario's Forestry Research Partnership: Progress and next steps.** For. Chron. 84(5): 756-763.

In this paper, the authors provide an overview of a two-phase approach used by the Canadian Ecology Centre-Forestry Research Partnership (CEC-FRP) to implement adaptive management on six forest management units in northeastern Ontario. They also summarize a self evaluation of the partnership using a set of attributes deemed necessary to successfully implement adaptive management (i.e., leadership; alignment with organizational goals; commitment, will, and capacity to act; and formal and explicit documentation). They conclude that the adoption of the two-phase approach, rather than direct implementation of adaptive management, provided the partners with the means to identify and address critical uncertainties related to intensifying forest management on Crown lands in Ontario, focus research and transfer activities, develop and test new landscape- and stand-level models, and adjust forest management policies and practices.

- Bell, F.W. and J.A. Baker. 2006. **Adaptive forest management.** Can. Silv. Mag. Nov (2006): 20-23.

This article advocates the use of silvicultural portfolios to meet forest management objectives and describes the applicability of alternative portfolios in the context of an adaptive management framework.

- Bell, F.W., D.G. Pitt and M.C. Wester. 2006. **Is intensive forest management a misnomer? An Ontario-based discussion of terminology and an alternative approach.** For. Chron. 82(5): 662-674.

The term forest management refers to the science and business of operating a forest property, which, on Crown lands in Ontario, is typically a forest management unit. Silviculture is a component of forest management that refers to the suite of stand-level activities used to control stand composition and growth. Intensive forest management (IFM) is a concept that has been discussed and considered in Ontario for at least 30 years. Originally, it referred to an intensively managed forest in which most stands are subject to relatively intensive silvicultural practices. Over time, both professional foresters and stakeholders began using the term IFM as if it were synonymous with intensive silviculture. As a result, IFM has been inappropriately used to reference stand-level activities in several published definitions and key policy documents, creating confusion among the science community, professionals, and the public. This confusion has made it difficult to implement aspects of the 1999 Ontario Forest Accord, which calls for the use of IFM (meaning intensive silviculture) to increase forest growth and productivity in some areas to offset the withdrawal of lands for parks and protected areas in others. In this paper, the authors call on forest managers to use the term IFM correctly and to portray forest management to stakeholders as consisting of a portfolio of natural and/or anthropogenic disturbance regimes. Using this approach, forest managers could more meaningfully define the intensity of forest management and silviculture on their land base.

- Bell, F.W. 2007. **Management of white pine ecosystems in Ontario: From exploitative to adaptive.** Can. Silv. Mag. Feb(2007): 10-13.

In this article, the author suggests that adaptive management, or learning by doing, has been applied in forest management in Ontario since the late 1800s. This premise is examined using the history of white pine management in Ontario as a case study. The author advocates for a transition from passive to active adaptive management.

- Bell, F.W. and D.G. Pitt. 2007. **Seasonal susceptibility of boreal plants: red raspberry phenology as a bioindicator of optimum within-season timing of glyphosate applications.** For. Chron. 83(5): 733-741.

In Canada, forest managers operating under public licenses are under pressure from the public to cease the use of herbicides or at minimum reduce the quantity of active ingredient applied in the environment. Lacking in their decision-making toolbox is information about biological cues that could help to optimize herbicide performance. In 1990, two rates of the herbicide glyphosate, 1.1 and 1.7 kg acid equivalent ha⁻¹,

were applied bi-weekly between July 21 and September 25 using a backpack sprayer to release jack pine seedlings from red raspberry competition. On average, the higher application rate reduced raspberry cover by at least 6% more than the lower rate ($p < 0.01$). Control of raspberry was poor with the earliest application, peaked with mid- to late summer applications, and decreased with late-season applications. Peak jack pine performance, as measured by stem volume index, followed a mid-August application at the low rate. Earlier applications resulted in substantial herbicide injury and later applications were not as effective at reducing raspberry competition. The optimum timing for jack pine performance corresponded with the period between the beginning of raspberry's florican senescence (i.e., end of full flowering) and the initiation of primocane senescence (i.e., fruit maturation). Seedlings released in mid-August maintained a growth advantage over other seedlings from the fifth through to the tenth year of this study. Discerning forest managers may choose to use phenological cues from the target species, such as red raspberry, as a bioindicator of glyphosate efficacy.

Bell, F.W., J.A. Baker, G. Bruemmer, J. Pineau and A. Stinson. 2008. **The Canadian Ecology Centre - Forestry Research Partnership: Implementing a research strategy based on an active adaptive management approach.** For. Chron. 84(5): 666-677.

Between April 2000 and March 2007, the Canadian Ecology Centre - Forestry Research Partnership funded, directed, or catalyzed approximately 145 projects. Most of these focused on knowledge and data acquisition, providing a solid foundation for a series of sensitivity and gap analyses to determine whether a long-term goal of enhancing productivity on six forest management units in Ontario was achievable, and more importantly, sustainable. A research strategy provided the focus for knowledge and data acquisition and the partnership facilitated integrated research, development, transfer, and implementation. In this paper, the authors provide an overview of these efforts, which are expected to position forest managers of the six forests to apply an adaptive management process to increase understanding of the response of their forests to various forest management policies and practices. The strategy and approach described could be useful to other jurisdictions aiming to more closely integrate forest research and operations as well as those interested in implementing adaptive management.

Bell, F.W., J. Parton, N. Stocker, D. Joyce, D. Reid, M. Wester, A. Stinson, G. Kayahara and B. Towill. 2008. **Developing a silvicultural framework and definitions for use in forest management planning and practice.** For. Chron. 84(5): 678-693.

Lack of a management framework on which to base silviculture options has plagued Ontario's forest management planning process. The Forest Management Planning Manual for Ontario's Crown Forests directs that strategic silvicultural options be developed and identified in terms of the (i) applicable forest unit, (ii) associated assumptions, and (iii) extent to which they can be used on a forest management unit. In this paper, the authors describe a framework for classifying management (or silviculture) intensity and propose definitions for extensive, basic, intensive, and elite silvicultural intensities to support the use of the framework in planning and application. The authors outline how the Canadian Ecology Centre - Forestry Research Partnership - a partnership between Tembec Inc., the Ontario Ministry of Natural Resources, and Natural Resources Canada - is considering applying the framework and definitions in the forest management planning process to develop strategic silviculture options within an active adaptive management approach. The framework should help to reduce uncertainties associated with forest development, treatment costs, response to treatments, and success rates provided appropriate monitoring. The framework and definitions described are specifically developed for silviculture related to reforestation of even-aged boreal forests.

Buse, L.J. (comp.). 2006. **Ontario Forest Research Institute publications 2001-2005: An annotated bibliography.** Ont. Min. Nat. Resour., Ont. For. Res. Inst., Sault Ste. Marie, ON. For. Res. Inf. Pap. No. 162. 49 p. + append.

This bibliography is a compilation of all publications written, co-authored, or commissioned by OFRI staff between 2001 and 2005. During this period over 200 publications were produced including three books, 87 journal articles, 26 reports, 11 technical notes, five newsletters, 47 papers/summaries in conference/workshop proceedings. Topics covered are diverse: understanding natural disturbance regimes and landscape dynamics, carbon budgets and effects of climate change on forests, results of 1998 ice

storm research, silviculture studies covering an array of topics from site preparation, tree improvement, stock production, planting, and vegetation management, to stand growth and yield, thinning, disease management, and harvesting for conifer, mixedwood, and hardwood forests in the boreal and Great Lakes region of Ontario. Author and subject indexes are provided.

Buse, L.J. and A.M. Obenchain. 2006. **Science Matters III: Integrating science and policy within MNR strategies - synopsis of presentations and discussions.** Ont. Min. Nat. Resour., Ont. For. Res. Inst., Sault Ste. Marie, ON. Int. Rep. 47 p.

This report provides an overview of the five plenary presentations and three discussion session context presentations, and includes all discussion session notes, and a summary of the evaluations of *Science Matters III: Integrating Science and Policy Within MNR Strategies*, held November 2005 in Sault Ste. Marie, ON. Participants chose among discussion sessions, which focused on aspects of the provincial wood supply strategy, forest sector competitiveness, and climate change. As in previous years, the event was well attended (81 participants) and well received. Overall, participants felt that the presentations at this year's session were interesting and informative and appreciated the focused theme discussion sessions. Recommendations included ensuring follow-up on actions from discussion sessions and continuing Science Matters with a similar format.

Buse, L.J. and A.H. Perera. 2006. **Applications of forest landscape ecology and the role of knowledge transfer in a public land management agency.** Pp. 129-156 in A.H. Perera, L.J. Buse and T.R. Crow (eds.) *Forest Landscape Ecology: Transferring Knowledge to Practice*. Springer. New York, NY.

In this book chapter, the authors examine progress in adopting a landscape ecological perspective within a public land management agency, with an emphasis on the role of knowledge transfer. They provide a summary of where forest landscape ecological knowledge is embedded in the Ontario Ministry of Natural Resource's policies and management directions, examine the socio-political drivers and supporting infrastructure that helped to ensure the available knowledge was adopted and applied in practice, outline the role of knowledge transfer, and identify some general lessons that may help other organizations to advance the adoption and use of landscape ecological knowledge and tools in policy, planning and practice. To illustrate their points, they rely on a current case study in which knowledge transfer was integrated from the outset.

Buse, L.J. 2007. **Science Matters V: Spotlight on the Boreal: Advancing science-policy integration for key forest management issues – synopsis of presentations, evaluations, and discussions.** Ont. Min. Nat. Resour., Ont. For. Res. Inst., Sault Ste. Marie, ON. Int. Rep. 21 p. + append.

This report includes a synopsis of presentations, discussions, and evaluations from the fifth annual research-policy networking event, which this year was focused on the boreal forest management issues.

Buse, L.J. 2008. **Science Matters VI: Working Towards Sound Forest Science and Policy to Support Ontario's Far North Planning Initiative - synopsis of presentations and discussions.** Ont. Min. Nat. Resour., Ont. For. Res. Inst., Sault Ste. Marie, ON. Int. Rep. 14 p. + append.

This report includes a synopsis of presentations, discussions, and evaluations from the sixth annual research-policy networking event, which this year was focused on the new Far North planning initiative.

Candau, J.-N. and R.A. Fleming. 2008. **Forecasting the response to climate change of the major natural biotic disturbance regime in Ontario's forests: the spruce budworm.** Ont. Min. Nat. Resour., Appl. Res. Develop. Br., Sault Ste. Marie, ON. Clim. Change Res. Rep. CCRR-13. 14 p.

Insect pests are a major, but often overlooked, ecosystem component that affect forest structure and function. Global climate change may substantially change the frequency and intensity of pest outbreaks, particularly at the margins of host ranges. The consequent shunting of carbon back to the atmosphere rather than to sequestration in forests as biomass may also influence global warming. This study focused on the spruce budworm because it is the dominant abiotic disturbance in Ontario forests. The intent was to improve

estimates of climate change effects on insect outbreaks and the resulting effects on carbon sequestration by: validating and analyzing the GIS data of Ontario's forest health survey records for spruce budworm defoliation and synthesizing the results; analyzing and developing models describing climate-insect outbreak relationships for spruce budworm in Ontario; and developing and applying a method for forecasting how climate change is likely to affect the severity and spatial locations of future insect outbreaks. In the first stage, this method was applied to survey records of spruce budworm defoliation in Ontario with the corresponding historical climate records. The frequency with which a site was defoliated was related to tree species composition and climate (i.e., temperature and precipitation at certain times of the year). In the final stage, predictions of future climate were incorporated to forecast how spruce budworm defoliation in Ontario might be affected by future climate change. In the resulting forecasts, the total area over which defoliation occurred increased because the area expanded northward but changed little in the south. Defoliation frequency mostly increased north of current areas of defoliation.

Chapman, K.A. and W.G. Cole. 2006. **Testing large-scale photography to sample plots for forest inventory in mixed and hardwood forests of the Great Lakes-St. Lawrence region of Ontario.** Ont. Min. Nat. Resour., Ont. For. Res. Inst., Sault Ste. Marie, ON. For. Res. Rep. No. 164. 22 p.

Large-scale photography (LSP, >1:1000) may be a useful tool to measure traditional and non-traditional forest attributes. LSP has worked well for plot-level forest sampling in boreal Canada, but has not been rigorously tested in mixed and hardwood forests, such as those of the Great Lakes-St. Lawrence region of Ontario, where forests have greater species diversity and often more vertical structure. The authors evaluated an LSP system for plot sampling in Great Lakes-St. Lawrence forests by comparing the utility of leaf-off and leaf-on imagery (1:433), assessing targeting accuracy, and comparing ground and LSP values for some commonly measured inventory, research, and monitoring variables (e.g., species identification, tree height, diameter), and for less commonly measured variables (e.g., canopy closure, hardwood tree quality, and snag and downed wood size and decay class). Spring, leaf-off imagery that captures phenological differences among species is optimal for identifying tree species and detecting and measuring plot variables in Great Lakes-St. Lawrence forests. In leaf-on images, foliage interfered with altitude measurement and thus photo scale determination, and obscured feature detection and measurement. Even with leaf-off imagery, the targeting accuracy of the system, which averaged 8.7 m, while reasonable for temporary sample plots used in most operational forest inventories may not be adequate for sampling or re-sampling permanent plots, depending on plot size. Likewise, LSP measurements of a variety of features may be adequate for forest inventory purposes, but not for repeated sampling of permanent plots. Differences between ground and LSP measurements were smaller for conifers than hardwoods (except poplar). These differences were quantified to help practitioners determine the suitability of LSP for their applications.

Chapman, K.A. and S.J. Colombo. 2006. **Early root morphology of jack pine seedlings grown in different types of container.** Scand. J. For. Res. 21(5): 372-379.

This study compared the effects of container type on early root system morphology of jack pine seedlings to determine impacts of container type on root characteristics that may be important for tree stability. Seedlings were grown for one season in Multipots®, Ventblocks®, Copperblocks®, Starpots®, and Jiffy® pellets, and for a second season in sand culture in pots. After the first growing season, roots that had grown between Jiffy plugs were cut using a knife, either early, in September, or late, in November. Seedlings produced in non-pruning containers, Multipots and Ventblocks, had more vertical structural roots, less even root distribution, and higher shoot:root mass after a second season. Seedlings grown in pruning containers, Copperblocks, Starpots and Jiffy pellets, had more horizontal structural roots and more evenly distributed roots. Jiffy seedlings had high shoot:root mass after pruning but ratios decreased to levels similar to that of Starpots and Copperblocks after a second season in pots. Early pruning of Jiffy seedlings removed less root mass than late pruning, but total live root mass of early and late pruned seedlings was similar after the potting trial. Pruning containers thus produced structural root forms with characteristics more desirable for tree stability. These characteristics were evident after the first season and persisted after the second season.

- Chen, H.Y.H., W. Byman and F.W. Bell. 2006. **Chemical site preparation influences productivity, composition, and structure of boreal mixedwoods in Ontario, Canada.** *For. Ecol. Manage.* 229(1-3): 145-154.

The authors examined the effects of chemical site preparation on jack pine and black spruce plantations 14 years after application on boreal mixedwood sites in Ontario, Canada. The experimental treatments were four rates of hexazinone (0, 1, 2, and 4 kg a.i. ha⁻¹ formulated as Velpar-L®) and two planting years (immediately and a year after herbicide application) in a split-plot design. At the individual-tree level, results supported findings from previously published short-term studies, i.e., increased crop tree diameter and volume growth with increasing hexazinone rates. At the stand level, volume of planted conifers did not increase with hexazinone rate for jack pine, but increased significantly for both container and bareroot black spruce. Planting immediately after hexazinone treatments resulted in greater crop tree and stand volume for both container jack pine and black spruce, but not bareroot black spruce. Total stand volume did not change with hexazinone rate or planting year, but stand composition shifted from hardwood-dominated to mixedwoods for both black spruce stock types while the compositional shift was less apparent in the jack pine plantations. An importance value used to describe height structure did not differ with hexazinone rate or planting year for jack pine. For black spruce plantations, importance values for non-crop conifer and hardwood decreased with increasing hexazinone rate, indicating a non-stratified, single-storied canopy structure on sites with high hexazinone rates and a stratified, two-storied structure on sites with lower hexazinone rates at early stages of stand development.

- Chen, J.X., S.J. Colombo, M.T. Ter-Mikaelian and L.S. Heath. 2008. **Future carbon storage in harvested wood products from Ontario's Crown forests.** *Can. J. For. Res.* 38(7): 1947-1958.

This analysis quantified projected carbon (C) storage in harvested wood products (HWP) from Ontario's Crown forests. The large-scale forest C budget model, FORCARB-ON, was applied to estimate HWP C stock changes using the production approach defined by the Intergovernmental Panel on Climate Change. Harvested wood volume was converted to C mass and allocated to four HWP end-use categories: in use, landfill, energy, and emission. The redistribution of C over time among HWP end-use categories was calculated using a product-based C-distribution matrix. Carbon emissions for harvest, transport, and manufacturing, as well as emission reductions from the use of wood in place of other construction materials and fossil fuels were not accounted for. Considering the wood harvested from Ontario Crown forests from 1951 to 2000 and the projected harvest from 2001 to 2100, C storage in HWP in use and in landfills is projected to increase by 3.6 Mt.year⁻¹ during 2001-2100, with an additional 1.2 Mt year⁻¹ burned for energy. Annual additions of C projected for HWP far outweighs the annual increase of C storage in Ontario's Crown forests managed for harvest, which is projected to increase by 0.1 Mt.year⁻¹ during the same period. These projections indicate that regulated harvest in Ontario results in a steadily increasing C sink in HWP and forests. Uncertainties in HWP C estimation are also discussed.

- Chen, J.X., S.J. Colombo, M.T. Ter-Mikaelian and L.S. Heath. 2010. **Carbon budget of Ontario's managed forests and harvested wood products, 2001-2100.** *For. Ecol. Manage.* 259(8): 1385-1398.

Forest and harvested wood products (HWP) carbon (C) stocks between 2001 and 2100 for Ontario's managed forests were projected using FORCARB-ON, an adaptation of the U.S. national forest C budget model known as FORCARB2. A fire disturbance module was introduced to FORCARB-ON to simulate the effects of wildfire on C, and some of the model's C pools were re-parameterized using data from Canadian forests. Forest C stocks were estimated using allometric equations that represent the relationships between C and net merchantable volume and forest age based on forest inventory statistics. Other pools were included using results from ecological studies related to forest inventory variables. Data from future forest development projections adopted in approved management plans were used as model input to produce forest C budgets for the province's Crown forest management units. The estimates were extended to other types of managed forests in Ontario: parks, measured fire management zones, and private forest lands. Carbon in HWP was estimated in four categories: wood in use, wood in landfill, wood burned for energy, and C emitted by wood decomposition or burning without energy generation. The authors projected that the C stocks in Ontario's managed forests and HWP (in use and in landfills) would increase by 465.3 Mt from 2001 to 2100, of which 47.9 Mt is from increases in forest C and 417.4 Mt is from HWP C.

Chiotti, Q., B. Lavender, K. Abraham, J. Casselman, S. Colombo, P. Crabbé, B. Crins, R. Davis, A. Douglas, P.A. Gray, L. Ignace, C. Lemieux, R. McAlpine, M. Obbard, C. O'Hara, J. Richard, C. Sadowski, D. Scott, M. Taylor and E. Wall. 2008. **Ontario**. Pp. 227-274 in *From Impacts to Adaptation: Canada in a Changing Climate 2007*. Gov. Can. Ottawa, ON.

This chapter presents an assessment of the most significant issues expected in Ontario as a result of climate change. It provides an overview of key current and future environmental, demographic, and economic conditions that influence vulnerability to climate change, summarizes what is known about climate sensitivities, effects, and adaptive capacity for three subregions of the province (south, central, and north), and highlights the risks and opportunities from a changing climate. Case studies are used to illustrate aspects of managing climate risks.

Cole, H.A., S.G. Newmaster, F.W. Bell, D. Pitt and A. Stinson. 2008. **Influence of microhabitat on bryophyte diversity in Ontario mixedwood boreal forest**. *Can. J. For. Res.* 38(7): 1867-1876.

As forest management intensifies, the conservation of forest biodiversity is a growing concern. Bryophytes are known to represent a considerable portion of plant diversity within northern forests. This is because bryophyte diversity is closely associated with microhabitat diversity. In this study, the influence of microhabitats on bryophyte diversity was investigated by comparing eight different boreal mixedwood microhabitats. The results indicate that bryophyte diversity (species richness, abundance, and evenness) is quite variable among microhabitats. The accumulation of species richness with microhabitat quantity within a forest stand also varies among microhabitats. Beta-diversity analyses indicate that the variety of microhabitats has considerable influence on community structure. Frequency analysis identified bryophytes that are restricted to or prefer particular microhabitats. Although all microhabitats are important to bryophyte diversity, decayed logs and rocks supported the greatest number of microhabitat-specific species, and rock microhabitats supported the largest total number of species. Recommendations for forest management, one of which emphasizes the need to recognize and manage the natural variety of microhabitats, such as downed woody material, found within the forests to conserve or restore bryophyte diversity, are provided.

Colombo, S.J. 2006. **How OMNR staff perceive risks related to climate change and forests**. *Ont. Min. Nat. Resour., Appl. Res. Develop. Br., Sault Ste. Marie, ON. Climate Change Res. Note. CCRN-02*. 8 p.

In this note, the author summarizes results of survey of a select group of MNR staff to gauge their perceptions of the seriousness of climate change as a forest management issue. Among the results: Of those staff surveyed, over 80% indicated that they believe human activities are a major cause of climate change but about 25% believe that the science of climate change is inconclusive. While some OMNR staff surveyed were unsure of the importance of climate change to forests and forest-based communities, most believe that climate change will significantly alter forest ecosystems and affect the communities that depend on them and that prompt action is required to address these effects.

Colombo, S.J. 2006. **The effects of lifting and handling on plant quality: The Ontario perspective**. In *Plant Quality: A Key to Success in Forest Establishment*. Proc COFORD Conf., Tullow CO Carlow, Natl. Council. For. Res. Devel. COFORD.

In this paper, the author presents an overview of the stresses that affect tree nursery stock during production, storage, and transport. He summarizes Ontario's tree seedling quality assessment program, describes the tests that are carried, and presents how the process might be applied to Irish forestry. In general, the author emphasizes the importance of careful stock handling practices in ensuring successful plantations.

Colombo, S.J. and C.W.G. Templeton. 2006. **Bud and crown architecture of white spruce and black spruce**. *Trees - Structure Function* 20(5): 633-641.

Needle primordia in buds and branch lengths were assessed in the crown of a plantation-grown white spruce tree. There was a gradation in needle primordia in buds in branches within the crown. The largest number of primordia was in the terminal bud of the leading main stem shoot, with the number in first-order whorl lateral shoot terminal buds decreasing from whorl one to whorl four, below which buds contained a similar small number of primordia (about one-third as many as in the terminal shoot). Previous year's shoot elongation

followed a similar pattern (i.e., elongation of whorl branches was greater closer to the top of the tree and elongation in the fourth through ninth whorls was about one-third that of the main stem leader). Higher order branches within whorls had within-branch gradation in shoot elongation and number of needle primordia, with older branches having as few as 16 to 30 primordia in buds and 3 to 4 cm elongation for high-order branches on older main stem whorls. The number of primordia in branch terminal buds were strongly correlated with branch length/diameter and bud length/diameter/volume. In both black spruce and white spruce, number of needle primordia in main stem leader terminal buds were strongly correlated with those in terminal buds of first and second whorl leaders.

Colombo, S.J., J. Chen and M.T. Ter-Mikaelian. 2007. **Carbon storage in Ontario's forests, 2000-2100**. Ont. Min. Nat. Resour., Appl. Res. Devel. Br. Sault Ste. Marie, ON. Clim. Change Res. Note. CCRN-06. 8 p.

In this note, the authors present decadal projections of carbon (C) stocks in Ontario's managed forests and wood products from 2000 to 2100. Projections were made using a forest C model, FORCARB-ON, modified from the U.S. national forest C model, FORCARB2, to represent Ontario forest conditions. Results are presented separately by type of forest management activity: managed Crown land, private land, parks, and the measured fire management zone. In addition, they provide estimates of C stored in wood products from actual harvest between 1951 and 2000 and from projected harvest after 2000. They project that 433 million tonnes of C will be sequestered in Ontario's forests between 2000 and 2100. This equates to an annual rate of C sequestration of 4.3 million tonnes between 2000 and 2100, equivalent to 15.9 million tonnes of carbon dioxide. The largest forest sink will be in wood products, accounting for 364 million tonnes of C storage over the century. Their results demonstrate the importance of assessing trends in forest C stocks over long periods to avoid short-term effects of changes in forest structure. They also concluded that the planned sustainable forest harvest in Ontario increases forest C over the long term.

Colombo, S.J., D.W. McKenney, K.M. Lawrence and P.A. Gray. 2007. **Climate change projections for Ontario: Practical information for policymakers and planners**. Ont. Min. Nat. Resour., Appl. Res. Devel. Br., Sault Ste. Marie, ON. Clim. Change Res. Rep. CCRR-05. 37 p.

This publication was intended to help planners and policymakers in Ontario account for the potential effects of climate change on people, infrastructure, and the environment. The overview of Ontario's future climate was based on the Canadian Coupled Global Circulation Model and used two scenarios of future greenhouse gas emissions resulting from human activity in the 21st century, the A2 and the B2 scenarios. The A2 scenario projects future greenhouse gas concentrations reaching the equivalent of 1,320 ppm carbon dioxide by the year 2100 (pre-industrial levels were about 330 ppm). The B2 scenario is based on lower greenhouse gas emissions compared to scenario A2, with the atmosphere reaching the equivalent of 915 ppm carbon dioxide by 2100. Potential temperature and precipitation changes are reported for both scenarios.

Colombo, S.J. 2008. **Ontario's forests and forestry in a changing climate**. Ont. Min. Nat. Resour., Appl. Res. Devel. Br., Sault Ste. Marie, ON. Climate Change Res. Rep. CCRR-12. 21 p.

This report updates a review of literature about the effects of global climate change on forest plants and communities published 10 years prior (Forest Research Information Paper No. 143). Since the previous review, evidence of environmental changes caused by elevated atmospheric carbon dioxide and its potential effects on global climate has strengthened considerably, to the point that there are reports that the effects of climate change are already being observed. Climate change will increasingly make species and local populations of tree species less well adapted to the climate where they occur. The long lives of trees and their slow natural migration means that natural processes will be unable to move seed fast enough to match changing climate. Increasingly, forest managers will consider planting non-local species and populations. Such potential adaptations, however, need to be carried out with consideration of potential consequences and if implemented should be well documented and monitored. Risks to forests from implementing adaptation strategies need to be weighed against the risks to forests and species biodiversity. A coordinated, science-based approach to forest adaptation can help forest managers determine possible strategies for reducing the negative effects of climate change. In this report, the authors describe an approach termed "judicious adaptation," in which risk of damage from implementing an adaptation is weighed against the risk of not acting. This approach is similar to adaptive management because of the requirements for planning

and monitoring in both. According to the IPCC, sustainable forest management that maintains forest carbon stocks and provides a sustained yield of wood products provides the best long-term climate change mitigation strategy for forests. Wood products from forests store carbon, but also can reduce greenhouse gas emissions from fossil fuels by using wood as an alternative energy source (either burned directly or burning methane generated by wood products in landfills). Solid wood products have considerably lower energy intensity than building materials such as steel, aluminum, brick, and concrete. Therefore, using wood in place of such other materials reduces emissions of greenhouse gases and is an indirect way that forests can contribute to mitigating climate change.

Colombo, S.J., B. Boysen, K. Brosemer, A. Foley and A. Obenchain. 2008. **Managing tree seed in an uncertain climate: Conference summary.** Ont. Min. Nat. Resour., Appl. Res. Devel. Br., Sault Ste. Marie, ON. Climate Change Res. Info. Note. CCRN-08. 8 p.

Climate change projections indicate that Ontario will experience increases in temperature and a risk of declining soil moisture. These changes will affect ecological conditions so much that trees from local populations, or even native species, may no longer be well suited to local climates. This perceived threat was the theme of a conference entitled *Managing Tree Seed in an Uncertain Climate*, held November 14-15, 2007 in Sault Ste. Marie, Ontario. Conference objectives were to build awareness about and discuss climate change and its potential impacts on forest genetic resources and to develop a road map for future actions that promote forest adaptation to future climates. Workshop participants identified 91 science needs; the top five were: improve understanding of how climate change will affect tree species; develop decision-support models to guide seed allocation; acquire ranges of projections for future levels of precipitation and soil moisture availability; document past cases of assisted migration and conduct and monitor studies of planting tree species and populations in locations of predicted migration; and learn more about species' ability to respond to climate in the absence of human intervention. Addressing the challenges of forest adaptation to climate change requires a well-thought-out approach to developing proactive policies and practices. In addition, more research is needed to improve understanding of species' responses and to integrate this knowledge as well as projections of future climate into a modelling framework.

Crow, T.R., A.H. Perera and L.J. Buse. 2006. **Synthesis: What are the lessons for landscape ecologists?** Pp. 205-214 in A.H. Perera, L.J. Buse and T.R. Crow (eds.) *Forest Landscape Ecology: Transferring Knowledge to Practice*. Springer. New York, NY.

In this book chapter, the authors summarize the main messages of the book, which include the need for and importance of active knowledge transfer in landscape ecology. They summarize the approaches to knowledge transfer presented in the case study chapters and make the case that transfer efforts benefit knowledge developers as well as proposing some next steps for landscape ecologists.

Cui, W. and A.H. Perera. 2006. **Forest fire size distribution in North American boreal forests: A state of knowledge.** Ont. Min. Nat. Resour., Ont. For. Res. Inst., Sault Ste. Marie, ON. For. Res. Inf. Pap. No. 163. 22 p.

The scientific, social, and economic significance of the knowledge of boreal forest fire regimes is becoming increasingly evident in North America. One synoptic indicator of fire regimes is the probability distribution of the fire size events, commonly known as the fire size distribution (FSD). Information about FSDs is crucial to designing long-term forest management plans that attempt to emulate forest fire regimes. The authors reviewed the scientific literature to examine the state of knowledge of FSDs with respect to underlying concepts, factors affecting the variability of FSD over time and space, research trends, and knowledge gaps. They found that no single probability distribution addresses all FSDs. There are reports of applications of Power law, negative exponential, Pareto, truncated power law, extremal, competing-hazards model distribution types. However, the power-law family, in particular the truncated power law, seems to be most representative of the mid-range of fire event sizes. Even then, the specific parameters of these probability distributions differ among geo-climate, forest types, and human influences such as fire management strategies. Even in a given space, FSDs may differ depending on the observation period as well as due to shifts in influencing factors such as climate. Therefore, it is essential to understand FSDs in their spatial and temporal context. The knowledge of FSDs in literature has many gaps. Present knowledge of FSDs stems from few scattered locations and mostly the mid-range of fire sizes. The complexities of factors that affect

FSDs are not clearly understood, even in the form of hypotheses, and most of this knowledge remains in descriptive form. Hitherto exclusive reliance on empirical methods to understand FSDs has many practical limitations, which may be partially overcome by simulation modelling methods, especially those that are process-based. Given the limitations of the scientific knowledge, the use of FSDs in practical applications must be judicious, with clear understanding of underlying assumptions and FSD variability over space and time.

- Cui, W. and A.H. Perera. 2008. **What do we know about forest fire size distribution, and why is this knowledge useful for forest management?** *Int. J. Wildl. Fire* 17(2): 234-244.

Forest fire size distribution (FSD) is one of the suite of indicators of forest fire regimes. It is applied in forest fire management, particularly for planning and evaluating suppression efforts. It is also used in forest management in the context of emulating natural fire disturbances. Given the recent growth in research and applied interest in this topic, the authors review and synthesize the state of knowledge on FSD, and identify sources of knowledge uncertainties and future research directions. Based on the literature, it is common for forest fires to follow the power law probability distribution, particularly the truncated subtype, under a variety of forest types and forest and fire management practices. Other types of FSD are also observed, but under specific circumstances. Although there is evidence that observed FSDs vary both over space and time, the knowledge is too fragmented to generalize the cause-effect relationships for such variation. As well, it is not clear how the various methods of studying FSD and their spatio-temporal scales influence derivations of FSDs. The authors suggest that a hypothetico-deductive research approach, combining empirical studies with process-based simulations is an effective means to advance the knowledge of FSD. They also suggest caution in the use of FSD in forest management because applying different distributions or even different parameters for the same distribution may affect fire size class and thus have different implications for forest management.

- Cui, W. and A.H. Perera. 2008. **A study of simulation errors caused by algorithms of forest fire growth models.** *Ont. Min. Nat. Resour., Ont. For. Res. Inst., Sault Ste. Marie, ON. For. Res. Rep. No. 167.*

Forest fire growth models (FGMs) simulate fire spread over spatially heterogeneous forest landscapes and over long periods with changing weather conditions. It is challenging to validate these models. The simulation errors of a FGM arise from three major sources: the availability and quality of input data, the theoretical basis of the fire behaviour model, and the fire growth algorithm. Errors caused by the algorithm are an indicator of the algorithm performance of FGMs. The authors studied the errors by assessing the algorithm performance of three FGMs: in BFOLDS (Boreal Forest Landscape Dynamics Simulator), Prometheus, and Wildfire. They examined the shapes and sizes of simulated fire perimeters compared to those predicted by the Forest Fire Behaviour Prediction (FBP) system under four spatial resolutions, five wind directions, and two spatial configurations of fuel type, keeping weather, topography, and other input data constant. Two new indices were used for error analysis. Our results suggest: (a) large fire simulation errors were caused by the fire growth algorithms of all three FGMs; (b) finer spatial resolutions did not necessarily produce more accurate predictions for BFOLDS and Prometheus; (c) simulation errors occurred mainly in the direction of head fire for all three models; and (d) the event-driven, continuous time advancing algorithm helps reduce error accumulation.

- Cui, W., M.R. Ouellette, A.H. Perera and M. Gluck. 2009. **Using BFOLDS to characterize fire regimes: A case study from a boreal forest landscape.** *Ont. Min. Nat. Resour., Ont. For. Res. Inst., Sault Ste. Marie, ON. For. Res. Rep. No. 173.* 41 p.

Forest fires are the result of complex interactions of weather and vegetation and are highly probabilistic. Characterizing forest fire regimes, the synoptic properties of spatio-temporal variability of individual fires, is important for many forest and fire management purposes. BFOLDS 1.0 (Boreal Forest Landscape Dynamics Simulator) simulates forest fires and forest succession for large areas over long periods. Resulting fire regime simulations are emergent properties of many stochastic and spatially explicit model processes as well as user assumptions and input data. Here the authors demonstrate the use of BFOLDS in characterizing a forest fire regime, using a large boreal ecoregion as an example and readily available forest cover and spatial weather data as primary input. The simulation period was 200 years and simulations were replicated 30 times to capture the stochastic variability in spatial and temporal patterns of forest fires. In addition, they

present several examples of quantitative indicators that characterize different aspects of a fire regime. These indicators include annual burn fraction (overall, by age class, and by forest cover type), fire return interval, fire size distribution, and burn probability (overall, by age class, and by forest cover type) and their spatial, temporal, and stochastic variability.

- Cui, W. and A.H. Perera. 2010. **Quantifying spatio-temporal errors in forest fire spread modelling explicitly.** *J. Environ. Inform.* 16(1): 19-26.

Forest fire growth models (FGMs) are widely used in both research and practice. FGMs involve modelling complex physical-chemical dynamic processes over large spatially heterogeneous forest landscapes and long periods under changing weather conditions. Because of their complexity, it is difficult to validate these models. A typical approach is to graphically compare predicted boundaries to the corresponding boundaries of actual fires, which provides a visual rather than quantitative evaluation of modelling errors of forest fire spread. In this paper, the authors propose a method to quantify two-dimensional spread process modelling errors, in this case for forest fire spread modelling. They introduce several indices that can be used to quantify spatio-temporal modelling errors of two-dimensional spread processes explicitly and to evaluate overall modelling errors. They demonstrate the effectiveness of the indices through a case study in which the modelling errors of a forest fire simulated by a FGM are compared with those of a reference fire. The case study illustrates that the spatio-temporally explicit indices do work to quantify modelling errors of forest fire spread compared to a reference model and that this error analysis is not only useful for validating FGMs but also provides a basis for improving them. Because of the similarity of other two-dimensional spread processes to forest fire spread, they suggest potential applications of the method in other spatial spread processes, such as the spread of forest insect and contagious disease, as well as the method's limitations.

- Dalziel, B.D. and A.H. Perera. 2009. **Tree mortality following boreal forest fires reveals scale-dependent interactions between community structure and fire intensity.** *Ecosystems* 12(6): 973-981.

Fire disturbance patterns influence forest communities at a range of spatial scales. Forest community structure may also influence fire disturbance patterns, because tree species vary in their fuel value and tolerance to fire damage. However, the influence of community structure on fire disturbance likely depends on latent ecological differences among fires and on the spatial scale at which patterns are observed. Using data on fire intensity, community structure, and post-fire tree survival in four systematically sampled boreal forest fires, the authors tested the hypotheses that patterns in post-fire tree survival reflect interactions between fire intensity and community structure and that these relationships change with the spatial scale of observation. To test the first hypothesis, they used information theoretic methods to compare eight generalized linear mixed effects models describing the influence of community structure and fire intensity on tree survival in a 500 m² sample plot, accounting for latent fire-to-fire differences in response. To test the scaling hypothesis, they reaveraged the data at nine successively larger spatial resolutions up to approximately 2 km², at each resolution tracking the parameter values of the best model. When fit to the plot-level data, the dominant feature of the best model was a strong intensity-survival correlation, which varied from fire to fire and depended on plot-level community structure. In some fires, community structure and survival were more tightly coupled at larger scales, whereas fire intensity became less important. These results support the view that fire disturbance patterns are influenced by cross-scale interactions between community structure and fire intensity.

- Dampier, J.E.E., F.W. Bell, M. St-Amour, D.G. Pitt and N.J. Luckai. 2006. **Cutting versus herbicides: Tenth-year volume and release cost-effectiveness of sub-boreal conifer plantations.** *For. Chron.* 82(4): 521-528.

Few cost-effectiveness studies of vegetation management in conifer plantations are reported in the literature. This study provides follow-up cost-effectiveness analysis from research conducted at the Fallingsnow Ecosystem Project in northwestern Ontario, Canada, with the objective of determining the relationship between release treatment costs and planted white spruce stem volume (\$ m⁻³) 10 years after alternative release treatments. Treatment cost estimates for 2003 were calculated by applying 1993 time-study data to estimated 2003 market costs for each treatment component. Untreated control plots had no treatment costs and were not included in the analysis. Including them will always suggest that doing nothing will be the most cost-effective, regardless how limited spruce volume is. The most cost-effective treatment was the aerial

application of herbicide Vision (\$12.16 m⁻³), followed by the aerial application of herbicide Release (\$12.18 m⁻³), cutting with brushsaw (\$38.38 m⁻³) and mechanical tending by Silvana Selective (\$42.65 m⁻³). Costs did not differ between the herbicide treatments ($p = 0.998$) or between the cutting treatments ($p = 0.559$). The herbicide treatments were three-fold more cost-effective than the cutting treatments ($p = 0.001$). In this analysis only the planted conifer component of these young stands was considered.

Dampier, J.E.E., N. Luckai, F.W. Bell and W.D. Towill. 2007. **Do tree-level monocultures develop following Canadian boreal silviculture? Tree-level diversity tested using a new method.** *Biodiv. Conserv.* 16: 2933-2948.

Concern about forestry practices creating tree-level monoculture plantations exists. In this study, the authors investigated tree diversity responses for six early seral boreal forest plantations in Ontario, Canada, representing three conifer species: black spruce, white spruce, and jack pine; 14 release treatments; and 94 experimental units. Dominance-diversity curves and Simpson's indices of diversity and evenness indicated tree alpha diversity. They propose a new method for assessing diversity, using percentage of theoretical species maximum (%TSM) which is determined by comparing post-disturbance richness (S) with a theoretical species maximum (TSM). Their results indicated that alternative vegetation release treatments generally do not reduce tree species diversity levels (%TSM) relative to untreated plots and that tree monocultures do not develop after vegetation release.

Doblas-Miranda, E., D. Kneeshaw, P. Burton, B. Cooke, M.-J. Fortin, D. MacLean, R. Man, M. Papaik and B. Sturtevant. 2009. **Mitigating the effects of insect outbreaks for sustainable forest management.** Sustainable Forest Management Network, Edmonton, AB. SFM Netw. Res. Note Ser. No. 48. 6 p.

Insect outbreaks in boreal and sub-boreal ecosystems can have more effect on wood fibre supply than do wildfires. This is partly because large-scale and synchronized regional outbreaks can overwhelm the capacity of forest managers to deal with outbreaks effectively. Managers also face considerable uncertainty and knowledge gaps when managing forests affected by insect outbreaks. However, current scientific knowledge about insect outbreaks is considerable. Thus, despite uncertainties about outbreak frequency and intensity, well planned and properly coordinated short- and long-term forest management choices may reduce losses and improve forest resilience to future outbreaks. In this note the authors propose some general and preliminary considerations to: (1) identify issues and challenges in insect outbreak mitigation; (2) provide guidance for short- and long-term tactics and strategies; and (3) highlight some remaining uncertainties.

Drescher, M., A.H. Perera, L.J. Buse, K. Ride and S. Vasiliauskas. 2006. **Identifying uncertainty in practitioner knowledge of boreal forest succession in Ontario through a workshop approach.** *Ont. Min. Nat. Resour., Ont. For. Res. Inst., Sault Ste. Marie, ON. For. Res. Rep.* 53 p. + append.

Expert knowledge of boreal forest succession is used widely in forest management in boreal Ontario, but the level of uncertainty of this mainly implicit knowledge is unknown. Therefore, in this study expert knowledge of boreal forest succession was elicited, its uncertainty quantified, and the sources of this uncertainty investigated. During two multi-day expert workshops in Ontario's Northwest and Northeast Region, groups of forestry experts reviewed available expert knowledge of post-fire establishment and natural succession. After confirming or adapting the available knowledge, experts estimated their confidence in the knowledge and perceived knowledge complexity. Estimates of confidence and complexity were combined to quantify individual expert knowledge uncertainty. Among-expert variability was quantified as an estimate of collective expert uncertainty in succession knowledge. Individual expert uncertainty and among-expert variability were combined to quantify composite expert uncertainty. The levels of these elements of knowledge uncertainty were investigated and associations of confidence, complexity, and collective expert uncertainty with forest cover type and site conditions assessed. Expert confidence in forest succession knowledge and perceived complexity of the knowledge were mainly medium, leading to high individual uncertainty. Collective uncertainty was lower for post-fire establishment than for natural succession knowledge, leading to lower composite uncertainty for post-fire establishment. Knowledge uncertainty elements were less often associated with forest cover type and site conditions for post-fire establishment than for natural succession, possibly because local factors are less important for vegetation dynamics immediately after fire. Knowledge uncertainty elements were most often associated with standard forest unit, but no clear pattern among forest

units emerged. Uncertainty elements were also associated with leaf type, tending to be lower for coniferous forest units than for hardwood and mixedwood forest units. Uncertainty elements were occasionally associated with site conditions, tending to be lower for dry or saturated and poor or organic sites than for moderate sites. Results indicated that uncertainty of forest succession knowledge in Ontario is variable, but often high, and can sometimes be related to ecological factors. A decrease in the existing knowledge uncertainty would increase forest management effectiveness.

Drescher, M., A.H. Perera, L.J. Buse, R. Arnup, C. Bowling, D. Etheridge, G. Niznowski, K. Ride and S. Vasiliauskas. 2008. **Boreal forest succession in Ontario: An analysis of the knowledge space**. Ont. Min. Nat. Resour., Ont. For. Res. Inst. Sault Ste. Marie, ON. For. Res. Rep. No. 171. 51 p. + append.

Reliable knowledge of forest succession is vital for successfully designing management strategies leading towards desired future forest states. At present two main sources of knowledge of forest succession are used: experienced practitioners (experts) and published research studies (literature). The contents of these two sources may overlap, but their interactions are implicit and fuzzy and the choice of which is used in forest management applications appears often arbitrary. Hitherto, no rigorous efforts have been made to explore these two knowledge sources for their respective strengths and weaknesses or to examine their concordance and possibilities for integration. The broad goal of the work reported here was to explore the body of boreal forest succession knowledge, to elucidate its strengths, weaknesses, and gaps, and to quantify its levels of uncertainty. Results indicated that expert knowledge of boreal forest succession is extensive, but contains a high degree of uncertainty in some aspects. For example, effects of mesic site conditions on forest succession and the generalized patterns of succession in species-rich forest types appeared to be less known than succession under extreme site conditions and immediately post-fire. Published knowledge is abundant for simple forest types and pioneer species, such as jack pine, relative to, for example, lowland coniferous forests. Overall, knowledge of the effects of site conditions on succession and the patterns of succession in species-rich mixed forests is sparse. Knowledge of natural succession from the two sources was most congruent in southeast boreal Ontario, and least in northwest boreal Ontario. Published knowledge revealed similarities in natural succession patterns among ecogeographical regions despite differences in succession postulated by expert knowledge. To augment the present body of knowledge, the authors identified three key areas for research: forest succession following non-stand replacing disturbances, especially in late successional forests; effects of site conditions on post-fire establishment; and succession dynamics in mixed forests. They also recommend placing concerted effort on quantifying the currently qualitative and descriptive knowledge to facilitate its use in simulation models and decision support systems that have become increasingly popular as management tools. These efforts must consider the need to spatially scale up stand level knowledge to the landscape level, as well as infusing the stochasticity and variability inherent to forest succession, to match the broadening scales of forest management planning.

Drescher, M., A.H. Perera, L.J. Buse, K. Ride and S. Vasiliauskas. 2008. **Uncertainty in expert knowledge of forest succession: A case study from boreal Ontario**. For. Chron. 84(2): 194-209.

Expert knowledge of forest succession is used widely in forest management planning, but its level of uncertainty is unknown. Using boreal Ontario as an example, the authors examined the level of uncertainty in expert knowledge of forest succession and explored possible sources of this uncertainty. Overall, the level of uncertainty associated with expert knowledge was high for all aspects of forest succession, except for post-fire species establishment. Higher levels of uncertainty were associated with knowledge of forest succession for mixed forest types and moderate site conditions, as opposed to coniferous or non-coniferous forest types and extreme dry/wet or poor/rich sites. The authors hypothesized that uncertainty in expert knowledge is highest when vegetation dynamics are highly stochastic as with complex species assemblages, environmental controls on succession are weak, and effects of disturbances are less drastic. Awareness about the degree of uncertainty in expert knowledge of forest succession could be incorporated into forest management decision processes. It could also help researchers to identify critical knowledge gaps to guide further studies.

Drescher, M. and A.H. Perera. 2010. **A network approach for evaluating and communicating forest change models.** *J. Appl. Ecol.* 47(1): 57-66.

Knowledge of forest change is often formalized in state-and-transition models (STMs). These models generate forecasts of forest condition that are widely used for forest management planning. Common techniques for evaluating such models are complex, requiring specialized skills not available to non-modellers. Consequently, model transparency can be limited, hampering collaborative resource modelling that otherwise may increase the chances of management success. The authors demonstrate evaluation of STMs through network visualization that produces intuitively accessible results, comparable to results of more commonly applied, complex techniques. To evaluate this approach, they statistically tested model similarities with empirical data. As examples, they used STMs of forest change, alternately parameterized with information from experts and literature, and compared them to empirical reference information. Graph theoretical analyses revealed differences in structure and dynamics between alternate STMs. For example, compared to empirical STMs, expert STMs were less complex while literature STMs were more complex. Overall, expert STMs were less similar to empirical STMs than were literature STMs, suggesting information in the expert STMs may deviate more strongly from empirical reference data. They speculate that differences between expert and empirical STMs result from lower complexity of mental models compared to empirical data. While they illustrated an approach using a simple matrix model, it could be adapted for more complex STMs. Improvements of the proposed approach could involve representing forest change rates with waiting times depicted by multigraphs. Synthesis and applications include: Common evaluations of forest change STMs involve complex techniques not easily accessible to non-modellers; approaching such models as networks makes their evaluation and statistical testing intuitively accessible to many audiences; benefits of this approach to modellers include improved communication about models with non-modellers, while benefits to stakeholders and decision makers include enhanced understanding of models. Overall, this may aid a collaborative resource modelling process and should improve the chances of successful resource management plan implementation. While they used an example from boreal forests, the approach could be applied to many other vegetation types globally.

Drescher, M. and A.H. Perera. 2010. **Comparing two sets of forest cover change knowledge used in forest landscape management planning.** *J. Environ. Plan. Manage.* 53(5): 591-613.

Forecasts of future resource states are central to resource management planning. Many simulation models and planning tools are used to produce such forecasts and apply knowledge of resource change dynamics as key input. Consistency among knowledge sources is therefore important to avoid knowledge ambiguity and uncertainty in resource forecasts and management plan outcomes. Using Ontario's boreal forest landscape as a case study, the authors examined two knowledge sources of forest resource change, practitioner expertise and research studies, commonly applied in plans and policies for large forest landscapes. The two knowledge sources were quantitatively compared by constructing networks of forest cover change for both sources and determining their agreement in structure and transition times. Some networks agreed well, indicating little knowledge ambiguity and comparatively low uncertainty if they were used to forecast forest landscapes. Other networks showed low agreement, thus indicating higher knowledge ambiguity and a dilemma of choice for forest landscape planners who may have to select from these knowledge sets. It is suggested that knowledge disagreements may be widespread in knowledge-driven management planning of many natural resource types and their causes similar. These disagreements signal areas of knowledge uncertainty, where resource planners must address resulting uncertainty of management outcomes and research should focus on improving resource change knowledge.

Fu, S., F.W. Bell and H.Y.H. Chen. 2007. **Long-term effects of intensive silvicultural practices on productivity, composition, and structure of northern temperate and boreal plantations in Ontario, Canada.** *For. Ecol. Manage.* 241(1): 115-126.

Long-term interactive effects of site preparation, brush control, and fertilization treatments on productivity, composition, and structure were examined on jack pine, black spruce, white pine, and white spruce plantations, 15 years after planting in Ontario, Canada. For all crop species, growth performance increased significantly with site preparation intensity on sites without brush control, but did not change on sites with brush control. The effect of brush control and site preparation on stand volume of crop trees varied among

plantations while fertilization had no effect. For the jack pine plantation, stand volume of crop trees increased with brush control and site preparation intensity, while volume of non-crop trees did not differ among treatments. For the black spruce plantation, brush control increased and site preparation marginally affected stand volume of crop trees. However, brush control decreased non-crop tree hardwood volumes, resulting in a significant increase in total stand volume. In the white pine and white spruce plantations, stand volume of crop trees increased while that of non-crop trees declined, resulting in no difference in total stand volume. However, there was a significant shift of stand composition from hardwood dominated, mixed, to crop trees dominated with silvicultural intensity. Height structure changed with increasing silvicultural intensity for all plantations, showing a shift from a hardwood dominated multi-layer canopy (a canopy of two or more layers mixed of crop trees and non-crop trees) to a crop tree dominated canopy with an understory of naturally established shade-tolerant seedlings. The authors concluded that intensive silviculture is a useful tool for managing stand composition and structure of boreal and northern temperate plantations, but increases in total stand volume may not occur as expected.

- Fu, S., H.Y.H. Chen, F.W. Bell, M. Sharma, J.R. Delaney and G. Peterson. 2008. **Effects of timing of glyphosate application on jack pine, black spruce, and white spruce plantations in northern Manitoba.** For. Chron. 84(1): 37-45.

Deferring conifer release treatments is sometimes necessary, but its effects on crop tree performance are not well understood. The effects of deferring glyphosate applications on jack pine, black spruce, and white spruce plantations established on a dry site with moderate competition and a moist site with heavier competition in The Pas, northern Manitoba were assessed. At each site, experimental treatments included no herbicide and one glyphosate (formulated as Vision) at 1.42 kg acid equivalent ha⁻¹ application between one and five years after planting with three replications. Survival, root collar diameter, and height of the three conifers were repeatedly measured for 10 consecutive years following planting. Survival of the three conifers was not affected by glyphosate application. For all species, root collar diameter and stand volume of crop trees increased significantly in glyphosate-treated plots, compared to control plots. Varying the timing of glyphosate application between the first and fifth year resulted in conifer of similar dimensions. Glyphosate application significantly improved height growth of black spruce and marginally white spruce, but not jack pine. On these sites, glyphosate reduced the cover of woody species, but grass, forbs and shrubs rapidly captured the newly available growing space. A two variable regression analysis revealed that grass cover negatively affected stand volume of all three conifer species. Cover of tall shrub, forbs, and interaction of cover and height of tall shrubs were the next most important variables to explain jack pine, black spruce, and white spruce volume growth, respectively.

- Genetics Research Program. 2007. **Breeding white pine for resistance to blister rust: Eastern white pine (*Pinus strobus* L.) and interspecific hybridization.** Ont. Min. Nat. Resour., Ont. For. Res. Inst., Sault Ste. Marie, ON: Brochure.

This bilingual brochure describes efforts by forest genetics researchers at the Ontario Forest Research Institute to breed blister rust resistant white pine seedlings.

- Gleeson, J., A. Zeller and J.W. McLaughlin. 2006. **Peat as a fuel source in Ontario: A preliminary literature review.** Ont. Min. Nat. Resour., Ont. For. Res. Inst., Sault Ste. Marie, ON. For. Res. Inf. Pap. No. 161. 23 p. + append.

Ontario's peat resources are extensive with approximately 16 million hectares, accounting for 20% of Canada's total peat deposits, occurring primarily in remote areas in the Hudson/James Bay lowlands. In response to renewed interest in the potential of peat as a fuel source, the authors reviewed the literature to address key considerations including the economic viability and associated socio-economic and environmental effects of fuel peat extraction. They found that a key issue associated with fuel peat extraction is the ongoing debate about the economic value of peat harvesting relative to the economic and ecological values of natural peatlands. While economic valuation of ecological functions, uses, and resources rarely occurs, science-based methods to do this are available. Here the authors attempt to inform the debate by defining the role of peatlands in both northern economic development and ecological sustainability. Another issue that emerged from this review is that knowledge of and experience with wet mining extraction is

minimal. Dry mining is most common for horticultural peat and involves sod cutting, vacuum extraction, or milled peat harvesting. This differs greatly from wet mining, which involves the removal of peat without on-site solar drying and transport to a plant for further dewatering and thermal drying. Whereas extensive research and experience with dry mining extraction is available, uncertainty exists about the environmental effects and potential restoration approaches for wet mining. Finally, this review clearly illustrates that significant terrestrial, hydrological, aquatic, and climatic effects are associated with large-scale peat extraction in the medium to long term. Peat extraction affects both the features and functions of a peatland (and larger wetland complexes), for example, by reducing its size, decreasing biodiversity and species richness, affecting connectivity of wetland units, impairing hydrological conditions, and changing the volume, turbidity, and chemistry of discharge. In addition, extraction of fuel-grade peat alters the carbon balance of peatland ecosystems, contributing to net increases in greenhouse gas emissions to the atmosphere.

Gleeson, J., G. Nielsen and W.C. Parker. 2009. **Carbon offsets from afforestation and the potential for landowner participation in Ontario.** Ont. Min. Nat. Resour., Appl. Res. Devel. Br. Sault Ste. Marie, ON. Climate Change Res. Rep. CCRN-09. 4 p.

This note describes the results of two regional workshops designed to test a proposed afforestation carbon (C) quantification protocol for use in Ontario and solicit input from private landowners about basic features of afforestation programs that will increase their willingness to plant trees and participate in a future carbon market. Data from tree planting projects from each of the two regions in southern Ontario were used to identify elements of the proposed C accounting procedures needing improvements and evaluate the practical feasibility of the monitoring requirements. Results demonstrate that the development of an offsets market that includes afforestation projects can help to stimulate interest in afforestation efforts in Ontario. Landowners have diverse interests and motives for tree planting including economic benefits, broader societal benefits, and personal objectives. In most cases, the potential sale of C offsets is a value-added element and not a primary motivator for the landowners involved. Afforestation and C offset programs in Ontario will need to be designed to accommodate the needs and concerns of small private landowners.

Groot, A., R. Man and J. Wood. 2009. **Spatial and temporal patterns of *Populus tremuloides* regeneration in small forest openings in northern Ontario.** For. Chron. 85(4): 548-557.

The density, height, and diameter of trembling aspen sucker regeneration was assessed over a 10-year period in openings created by harvesting in a 40-year-old, 19-m-tall aspen stand in northeastern Ontario. The five types of opening comprised circular openings of 9- and 18-m-diameter, 150-m-long east-west strips of 9- and 18-m width, and a 1.5 hectare (100 m x 150 m) clearcut. Density of aspen regeneration was significantly affected by opening type, location relative to the opening, time since harvest, and by all interactions of these factors. Aspen densities within the circular openings declined to low levels by year 10, despite considerable initial recruitment. Trembling aspen height and diameter were significantly influenced by opening type, location relative to the opening, time since harvest, and by opening by time and location by time interactions. By year 10, trembling aspen heights in the circular openings were substantially less than those in the clearcut and strip openings. The results support the traditional view that aspen is best managed under the clearcut silvicultural system, and that trembling aspen regeneration following forest harvesting can be reduced by controlling the extent or intensity of overstory removal. Finally, the results suggest that disturbances that create gaps greater than one tree height in width in pure aspen or mixedwood forests may allow gap dynamics to ensue.

Jones, T.A., G.M. Domke and S.C. Thomas. 2009. **Canopy tree growth responses following selection harvest in seven species varying in shade tolerance.** Can. J. For. Res. 39(2): 430-440.

The authors used tree ring measurements to investigate the temporal response of basal area increment (BAI) of canopy trees following selection harvests by sampling across a chronosequence of stands with known harvest dates in tolerant hardwood (Great Lakes-St. Lawrence) stands in central Ontario. Seven tree species of various shade tolerances ranged widely in their responses to reduced competition. The more shade-tolerant species responded more positively: shade-tolerant species showed an average increase in BAI of 35% four to 15 years post-harvest compared with 16% for mid-tolerant species and -7.5% for intolerant species. All species showed a time-lag in post-harvest growth responses, with maximum growth responses occurring between three and 15 years post-harvest. Tree size was the most important factor determining the

magnitude of BAI response, with smaller trees consistently responding more than larger trees. The authors suggest that higher growth responses to selection harvests among shade-tolerant species may contribute to declines in mid-tolerant species abundance in selection-managed stands. More broadly, interspecific variability in canopy tree responses to forest disturbance appears to follow patterns distinct from seedling and sapling responses, with important implications to forest community dynamics in both managed and unmanaged forests.

- King, A.W. and A.H. Perera. 2006. **Transfer and extension of forest landscape ecology: A matter of models and scale.** Pp. 19-42 in A.H. Perera, L.J. Buse and T.R. Crow (eds.) *Forest Landscape Ecology: Transferring Knowledge to Practice*. Springer, New York, NY.

In this book chapter, the authors examine the generic barriers to the use of landscape ecological models, exploring issues such as scale, complexity, assumptions, and data limitations. As well they propose solutions to make models more attractive to resource managers. Finally, they outline the benefits to model developers of including interactive knowledge transfer in their model development efforts – better models that are applied appropriately in resource management.

- Latremouille, C., W.C. Parker, S. McPherson, F. Pinto, B. Fox and L. McKinnon. 2008. **Ecology and management of white pine in the Lake Abitibi (3E) and Lake Temagami (4E) ecoregions of Ontario.** Ont. Min. Nat. Resour., Ont. For. Res. Inst., Sault Ste. Marie, ON and Northeast Sci. Inf. Unit, South Porcupine, ON. Sci. Devel. Transf. Ser. . No. 004. 64 p. + append.

This technical report provides detailed information to support the *White Pine in the Lake Abitibi and Lake Temagami Ecoregions of Ontario* public report that is part of the Ontario Ministry of Natural Resources' *State of Resources Reporting* series. A general description of the climate, physiography, geology, soils, and vegetation of the Lake Abitibi (3E) and Lake Temagami (4E) ecoregions of northeastern Ontario is followed by a brief review of the ecology and silvics of white pine (*Pinus strobus* L.), with special reference to northeastern Ontario. The role of white pine in the settlement and economic development of Ontario, as well as the parallel evolution of forest management policy over the past 200 years, illustrates how the white pine resource was systematically depleted. This historical legacy is reflected in the current distribution, composition, and structure of white and red pine (*Pinus resinosa* Ait.) forests in northeastern Ontario. The current state of these forests, particularly in Ecoregion 3E at the northern limit of the natural range of white pine in Ontario, presents many challenges to management of this species for its many economic, social, and ecological values. Ontario's white pine forests are now managed according to the principle of conservation of biodiversity adopted under the *Crown Forest Sustainability Act*, using harvesting practices that emulate natural disturbances. Science-based forest policies and guides provide management direction for white pine to sustainable forest licensees operating on Crown forests. Based on their relative effectiveness in meeting a range of site- and stand-specific management objectives, including restoration and management for old growth white and red pine forests, a variety of silvicultural options are used to manage white pine in northeastern Ontario. A combination of monitoring, forest research and technology development, and an adaptive management approach is intended to improve the tools and silvicultural effectiveness of forest operations directed towards white pine management. Model simulations project that the use of current selected management practices will increase the total amount of white and red pine forest in both ecoregions 3E and 4E. By comparison, a short-term increase in the area of old growth white and red pine forests is forecast, followed by a decrease in both ecoregions. Future white pine wood supply is also projected to decrease because white pine forests are being increasingly managed for ecological and social values and because the final removal harvest of older shelterwoods that are not satisfactorily regenerating will be delayed. Continued development and application of improved operational management practices and increased silvicultural investment in regeneration of white and red pine forests are needed to address projected declines in old growth forest area and wood supply.

- Lautenschlager, R.A. and C. Nielsen. 2007. **Ontario's forest science research and extension efforts after the 1998 ice storm.** J. For. 105(1): 34-42.

The 1998 ice storm devastated major portions of south central Canada and the northeastern United States. After the storm, Ontario developed major communication and forest-focused research efforts designed to

improve understanding of the short- and longer-term ecological consequences of the storm, its economic consequences, and proactive approaches that could be developed to reduce damage in the future. In this article, the authors summarize results from the major aspects of that effort: (1) communications, (2) a fertilizer/competition control experiment designed to aid sugar maple recovery and document the physiological and stand-level ecological consequences of those treatments, and (3) the consequences of damage and postdamage management in woodlots, including plantations.

- Lu, P. and R.W. Sinclair. 2006. **Survival, growth and wood specific gravity of interspecific hybrids of *Pinus strobus* and *P. wallichiana* grown in Ontario.** For. Ecol. Manage. 234(1): 97-106.

Interspecific hybrids between eastern white pine (*Pinus strobus* L.) and Himalayan blue pine (*P. wallichiana* A.B. Jacks.) were created in Ontario, Canada, to introduce blister rust (caused by *Cronartium ribicola* Fisch.) resistance genes to the former. Here, the authors report the survival, growth, and wood specific gravity of these interspecific hybrids from field trials established between the 1970s and 1990s. Results indicate that while *P. wallichiana* generally performed poorly due to insufficient cold hardiness, progressive improvement in survival and growth was evident for the first generation hybrids (F1) and backcrosses (B1) to *P. strobus*, with a trend of better performance with increasing *P. strobus* parentage. In southern Ontario, where climatic conditions were relatively mild, some interspecific hybrids outperformed *P. strobus* in 20- to 40-year-old trials. In northern Ontario, insufficient cold hardiness limited the survival and growth of the interspecific hybrids. Measured wood specific gravity was highest for *P. wallichiana* and lowest for *P. strobus*, with that of the interspecific hybrids being intermediate. Implications of the field trial results to breeding for increasing blister rust resistance of eastern white pine are discussed.

- Lu, P., S.J. Colombo and R.W. Sinclair. 2007. **Cold hardiness of interspecific hybrids between *Pinus strobus* and *P. wallichiana* measured by post-freezing needle electrolyte leakage.** Tree Physiol. 27(2): 243-250.

Interspecific hybrids between eastern white pine (*Pinus strobus*) and Himalayan blue pine (*P. wallichiana* A. B. Jacks.) were developed in Ontario, Canada, to introduce blister rust (*Cronartium ribicola* Fisch.) resistance genes to *P. strobus*. There is concern that introducing blister rust resistance has resulted in reduced cold hardiness of the progeny compared with non-hybridized eastern white pine. To test the efficacy of backcrossing with *P. strobus* to improve cold hardiness, one-year-old seedlings from hybrid crosses differing in *P. strobus* genome composition were artificially freeze-tested. In Experiment 1, unhardened seedlings were allowed to acclimate to progressively lower temperatures in a growth room, whereas in Experiment 2, seedlings were hardened outdoors under natural weather conditions in Sault Ste Marie, Ontario. Needle cold injury was determined by calculating relative electrical conductivity based on post-freezing electrolyte leakage. Results indicated that needle fascicles from unhardened seedlings of all genotypes in the greenhouse tolerated -5°C for three hours with little or no injury. Cold hardiness increased in parallel with declining growth room minimum temperature over the seven-week period of hardening. Cold hardiness was improved for hybrid crosses with increased *Pinus strobus* genome composition in Experiment 2, but the results were less conclusive in Experiment 1.

- Lu, P. 2008. **A note on the relationship between estimates of heritability and type-B genetic correlation.** Can. J. For. Res. 38(11): 2917-2921.

This note verifies the applicability of an approach derived from Adams et al. (W.T. Adams, T.L. White, G.R. Hodge, and G.L. Powell. 1994. *Silvae Genetica* 43: 357-366) that used the ratio of unbiased to biased heritability estimates (denoted by $R-h$) to approximate type-B genetic correlation ($r(B)$) estimates. Both theoretical evidence and empirical evidence suggest that the estimate of the ratio of unbiased to biased heritability is often a good approximation of the estimate of type-B genetic correlation under the assumption of homogeneous heritability among sites. Given the large sampling errors and often unstable estimates of $r(B)$, the approach tested may provide an alternative to existing methods for estimating type-B genetic correlation.

- Lu, P. and P. Charrette. 2008. **Genetic parameter estimates for growth traits of black spruce in northwestern Ontario.** Can. J. For. Res. 38(12): 2994-3001.

Genetic parameters of growth traits were estimated for first-generation selections of black spruce in northwestern Ontario from 720 open-pollinated families and more than 42,000 trees. Unbiased estimates of narrow-sense heritability for tree height growth averaged 0.19, 0.18, and 0.14 at ages 6, 11, and 19 years, respectively, from combined-site analyses compared with 0.25, 0.23, and 0.16 for the same ages from single-site analyses. Heritability estimates for diameter at breast height and stem volume were lower than that of height at age 19, suggesting that tree height is a more desirable trait for selection in black spruce. The moderately high estimates of type B genetic correlations implied limited operational importance of genotype by environment interactions. Estimates of age-age genetic correlation were high (> 0.88) among cumulative tree height growth at 6, 11, and 19 years but lower between height increments from different age intervals. Estimates of type B age-age genetic correlation were more than 0.2 lower than their type A counterparts, suggesting strong effects of common environments on the estimates of type A genetic correlations. Based on the relative selection efficiencies, selection on cumulative tree height between ages 6 and 11 was more efficient than at age 19.

- Lu, P. and D. Derbowka. 2009. **Breeding eastern white pine for blister rust resistance: A review of progress in Ontario.** For. Chron. 85(5): 745-755.

White pine blister rust (caused by *Cronartium ribicola* J.C. Fisch.) is a primary cause of poor survival and growth of eastern white pine and has contributed to the species' decline across its range. Genetic resistance to blister rust is generally weak in eastern white pine, possibly owing to the absence of meaningful resistance alleles. Integrating major resistance genes from Eurasian five-needle pine species to white pine has been demonstrated to be effective through traditional plant breeding approaches. In this paper, the authors summarize progress from more than half a century of breeding and testing in Ontario.

- Man, R., G.J. Kayahara and J.A. Rice. 2006. **Eleven-year response of a boreal mixedwood stand to partial harvesting -- regeneration and vegetation attributes.** In Natural disturbance-based silviculture: Managing for complexity. Rouyn-Noranda, QC. UQAT. 4 p.

This popular summary provides 11-year results from a northeastern Ontario trial established in 1994 to examine the effects of partial harvesting on conifer growth. Overall, partial harvesting adequately protected advance conifer regeneration and accelerated the establishment and growth of conifers. It also effectively controlled hardwood regeneration density and thus competition with conifers. Based on the early development of conifers, hardwoods, and shrubs in the understory, partial cut areas will likely have a stronger hardwood component than the uncut areas.

- Man, R., G.J. Kayahara, J.A. Rice and G.B. MacDonald. 2008. **Response of trembling aspen to partial cutting and subsequent forest tent caterpillar defoliation in a boreal mixedwood stand in northeastern Ontario, Canada.** Can. J. For. Res. 38(6): 1349-1356.

The growth response and mortality of trembling aspen were monitored 1, 3, 5, and 11 years after partially harvesting an aspen-dominated mature mixedwood stand in northeastern Ontario. Both diameter aspen were severely suppressed by three years of moderate to severe defoliation by forest tent caterpillar. The diameter growth of surviving trees almost recovered, but due to continuous crown dieback in the six years after defoliation ceased, height growth did not. Over the 11 years after harvest, 70% of residual aspen died with 80% of that mortality occurring in the six years after defoliation. Trees in the lower canopy and in the partial cut had higher mortality rates than those in the upper canopy and in the uncut control. Increased mortality at the individual tree level was generally associated with greater foliage loss. Aspen growth and mortality were associated with defoliation levels, particularly for trees in partial cut treatments. Partial cutting and crown class strongly influenced the response of aspen trees to insect defoliation and should be considered when selecting residual trees during harvesting.

Man, R., G.J. Kayahara, J.A. Rice and G.B. MacDonald. 2008. **Eleven-year responses of a boreal mixedwood stand to partial harvesting: Light, vegetation, and regeneration dynamics.** For. Ecol. Manage. 255(3-4): 697-706.

Light, vegetation, and regeneration dynamics were monitored for 11 years as part of a partial harvesting experiment in an aspen-dominated boreal mixedwood stand in northeastern Ontario. The partial cut treatment removed 43% of the original overstory basal area. An outbreak of forest tent caterpillar between years three and five further reduced the original overstory (by about 22%, mainly aspen) in the partial cut and uncut treatments. Clearcutting increased the density of hardwood regeneration but reduced the amount of conifer regeneration compared with the partial cut and uncut treatments. Reducing the overstory canopy increased the height growth of hardwood regeneration, density of speckled alder – the dominant tall shrub on site, and understory light levels, but did not change the mean heights of conifer regeneration and shrubs. Harvesting generally did not affect the amounts of low understory vegetation, except mosses, which decreased significantly in cover in the clearcut. Although most of the conifer regeneration was still under hardwood regeneration and shrub layers, much of the advance conifer regeneration had reached over 4.0 m (large sapling) between years five and 11 in both partial cut and uncut treatments. From years five to 11, the residual overstory inhibited hardwood regeneration and understory shrubs even more, reducing density, height, and number of hardwood that became large saplings. Dynamics of regeneration and understory vegetation observed following harvesting compounded by a forest tent caterpillar infestation suggest that partial harvesting can promote the establishment and growth of shade-tolerant conifers (mainly balsam fir and some black spruce) and inhibit the development of shade-intolerant hardwood regeneration and understory vegetation. Future stand structure will likely consist mainly of hardwoods in the clearcut treatment, and mixed conifers and hardwoods in the partial cut and uncut treatments, with more hardwood in the partial cut. Further monitoring is required to verify this premise.

Man, R., G.J. Kayahara, Q.L. Dang and J.A. Rice. 2009. **A case of severe frost damage prior to budbreak in young conifers in northeastern Ontario: Consequence of climate change?** For. Chron. 85(3): 453-462.

In spring 2007, young planted and natural conifers suffered extensive needle and bud injury near Hearst and Kapuskasing in northeastern Ontario. Damage was observed on all species of conifers up to 20 years old and 8 m in height. Taller trees, especially those in the overstory, and young understory trees protected by a closed canopy had less damage. The damage was caused by earlier than normal loss of cold hardiness followed by late spring frosts. During May 19 to 21, 2007, minimum temperatures between -8 and -9°C were recorded, and before this period, temperatures were warm enough to induce early dehardening and loss of trees' cold hardiness. Based on the historical weather data for Kapuskasing, estimated budbreak time has become earlier since 1918 and freezing temperatures during budbreak and shoot elongation (between growing degree days 100 and June 15) have become more frequent since 1980. If the trend towards earlier budbreak is due to climate change, then the type of frost damage observed in northeastern Ontario in 2007 could become more common. The authors discuss implications of such events and suggest research needed to understand the risk of frost damage given changes in climate and ways to reduce damage.

Man, R., J.A. Rice and G.B. MacDonald. 2009. **Long-term response of planted conifers, natural regeneration, and vegetation to harvesting, scalping, and weeding on a boreal mixedwood site.** For. Ecol. Manage. 258(7): 1225-1234.

The authors report 14-year response of a boreal mixedwood stand to different harvest intensities (uncut, 50% partial cut with and without removal of residuals after three years, and clearcut), spot site preparation treatments (none and scalped), and chemical weeding frequencies (none, single, and multiple) in northeastern Ontario. The response variables include the survival and growth of planted white spruce and jack pine, height and density of natural regeneration and shrubs, and cover of shrubs and non-woody vegetation. Harvesting and weeding generally improved survival and growth of planted trees, although white spruce survival did not significantly differ among weeding frequencies. Harvesting increased heights of hardwood (mostly trembling aspen) and conifer (largely balsam fir) natural regeneration, cover and density of shrubs, and cover of herbs, lichens, and ferns. Chemical weeding reduced height, density and cover of shrubs, height and density of hardwood regeneration, and fern cover, but increased moss and lichen cover. Spot scalping did not significantly affect planted seedling, natural regeneration, or other vegetation. Maximum

survival and growth of planted white spruce and jack pine were achieved using a combination of clearcutting and multiple weeding. However, partial cutting followed by a single weeding produced acceptable survival and reasonable growth of planted trees, particularly for white spruce. Partial canopy removal alone substantially reduced the amount of hardwood regeneration, relative to clearcutting, but did not adequately suppress understory shrubs. Significant improvement in seedling growth following multiple weedings was evident primarily in the complete canopy removal treatments: 50% partial cut with removal of residuals after three years and clearcut. While the effects of harvesting and weeding on planted crop trees found in the fifth-year assessments generally persisted at year 14, survival decreased, likely due to light competition from developing hardwood and shrubs.

- Man, R. and P. Lu. 2010. **Effects of thermal model and base temperature on estimates of thermal time to bud break in white spruce seedlings.** *Can. J. For. Res.* 40(9): 1815-1820.

To improve the predictability of bud burst and growth of boreal trees under varying climate, the thermal time for bud break in white spruce seedlings was evaluated under a range of temperature conditions in controlled environment chambers. Thermal time requirements were calculated as the sum of growing degree days or growing degree hours above base temperatures ranging from -1 to 5°C. Results indicated that the common modelling approach, which uses a base temperature of 5°C and growing degree days, may not be appropriate for future climatic conditions. Estimates of thermal time requirements using a base temperature of 5°C varied considerably among temperature treatments and thus would reduce the predictability of bud burst under changing climate. In contrast, estimates of thermal time requirements with lower temperatures closer to 1°C were relatively consistent among treatments. Growing degree hour models were less sensitive to base temperature than degree day models. These results should help in the selection of appropriate base temperatures and thermal time models in studies to quantify thermal time for bud burst in other boreal tree species.

- Man, R. and J.A. Rice. 2010. **Response of aspen stands to forest tent caterpillar defoliation and subsequent overstory mortality in northeastern Ontario, Canada.** *For. Ecol. Manage.* 260(10): 1853-1860.

Overstory mortality, understory tree recruitment, and vegetation development were assessed in trembling aspen stands following two recent episodes of forest tent caterpillar defoliation in northeastern Ontario. The results suggest that poplar (aspen and balsam poplar) mortality increased with consecutive years of insect defoliation occurring from the mid-1980s to mid-2000s and the proportion of poplars in the overstory, but decreased with improved pre-defoliation tree vigour (DBH increment). The first outbreak, which lasted from the mid-1980s to early 1990s, was more severe in terms of insect defoliation and contributed more to poplar mortality and decline. The decline began in the late 1990s and peaked in early 2000s. Poplar regeneration and understory shrubs responded rapidly to foliage loss to insect defoliation and mortality of overstory poplars. The regenerated poplars were able to maintain their growth under developing shrubs and residual overstory canopy and numbers were sufficient to compensate for the poplar trees lost to insect infestation. The defoliation-induced overstory decline will accelerate the transition of aspen stands to conifer dominance through enhanced conifer recruitment and growth, and reduced hardwood overstory in aspen-dominated stands, while hardwood dominance will persist in pure aspen stands. From a timber supply perspective, the decline caused by forest tent caterpillar defoliation could delay the availability of aspen stands for harvesting by 40 to 50 years.

- Man, R., J.A. Rice and G.B. MacDonald. 2010. **Five-year light, vegetation, and regeneration dynamics of boreal mixedwoods following silvicultural treatments to establish productive aspen-spruce mixtures in northeastern Ontario.** *Can. J. For. Res.* 40(8): 1529-1541.

Given the extent of boreal mixedwoods in Canada and the challenges of maintaining their conifer component following harvest, the authors investigated the effects of intimate mixtures versus a mosaic spatial arrangement on mixedwood establishment and growth in northeastern Ontario. The silvicultural treatments were pre-harvest aerial herbicide spray, post-harvest ground herbicide in conifer corridors, partial cutting, conventional conifer plantation with post-harvest aerial herbicide, and an untreated reference stand. Fifth-year results suggest that pre-harvest herbicide application followed by clearcutting controlled trembling aspen regeneration density and height growth nearly as effectively as post-harvest herbicide in conifer

corridors or the conventional conifer plantation treatments. Partial cutting reduced aspen regeneration in both harvested and leave corridors but did not affect shrub cover. Survival of spruce regeneration did not differ among silvicultural treatments; however, more spruce seedlings progressed from small to intermediate height classes in the pre-harvest spray and partial cut than in the post-harvest herbicide treatment plots. Based on short-term responses in light availability, vegetation cover, and regeneration as well as cost comparisons among options, the treatment objectives were generally met: the stand has the desired species density and composition of a healthy and productive mixedwood.

McKenney, D.W., J.H. Pedlar, K. Lawrence, P.A. Gray, S.J. Colombo and W.J. Crins. 2010. **Current and projected future climatic conditions for ecoregions and selected natural heritage areas in Ontario.** Ont. Min. Nat. Resour., Ont. For. Res. Inst., Sault Ste. Marie, ON. Climate Change Res. Rep. CCRR-16. 26 p. + append.

The changes in global climate that have been projected for this century have major implications for the composition, structure, and function of ecosystems in Ontario. In this report, the authors present four approaches that summarize projected changes in climate across Ontario's ecosystems at two scales: for ecoregions and for selected natural heritage areas. First, the current climatic regime or "climate envelope" for each ecoregion is summarized and mapped for three future time periods (2011-2040, 2041-2070, 2071-2100); this shows where current ecoregion climatic conditions are projected to move as the century progresses. Second, climate summaries are provided for each ecoregion for the current and three future time periods to show how climate is projected to change within the currently defined ecoregion boundaries. Similarly, current and future climate summaries are provided for 29 selected natural heritage areas. Finally, to introduce the concept of climate-related movement of flora and fauna, current and future climate envelopes are generated for 12 Ontario tree species with differing climate and site type preferences. The extent to which these species' climate habitats are represented across Ontario's network of natural heritage areas is shown for current and future climate. The findings suggest that ecoregion climate envelopes will shift northward, becoming increasingly smaller and more scattered, and in some cases even disappearing, as the century progresses. These changes are driven by a northward shift in temperature combined with relatively stable precipitation patterns. Clearly Ontario's natural heritage areas will also be affected by these changes. For example, the annual mean temperature in Polar Bear Provincial Park is projected to increase from -4.5°C to nearly +2°C and the number of growing season degree days will more than double by the end of this century; this climatic shift would in principle make the park's climate suitable for the growth of sugar maple. This type of assessment is an important first step in projecting the effects of future climate on Ontario's ecoregions and natural heritage areas, and helps establish a basis for discussing and developing management strategies and policies to ensure the ecoregion framework remains relevant to land use planning in a rapidly changing climate. Together, these analyses provide novel perspectives on some of the challenges that resource managers are likely to face during the 21st century.

McLaughlin, J.W. and S.A. Phillips. 2006. **Soil carbon, nitrogen, and base cation cycling 17 years after whole-tree harvesting in a low-elevation red spruce (*Picea rubens*)-balsam fir (*Abies balsamea*) forested watershed in central Maine, USA.** For. Ecol. Manage. 222(1): 234-253.

Forest harvesting and regeneration may cause changes in soil and solution chemistry that adversely affect forest productivity and environmental quality. The objective of this study was to assess soil carbon (C), nitrogen (N), and base cation cycling 17 years following whole-tree harvesting in a low-elevation red spruce-balsam fir watershed (regenerating watershed) in central Maine, USA. Results for forest floor and mineral soil nutrient concentrations and pools were compared to an adjacent non-harvested 77- to 85-year-old spruce-fir watershed (reference watershed) and to pre-harvest conditions 17 years earlier. The total soil (forest floor + mineral soil) exchangeable magnesium (Mg) pool was 32% and 44% lower ($P = 0.05$), respectively, in the regenerating and reference watersheds compared to the pre-harvest condition. Nitrogen and exchangeable potassium (K) contents in the forest floor, however, were 26% and 65% lower ($P = 0.05$), respectively, for the pre-harvest condition compared to the reference watershed; no differences ($P > 0.05$) were evident between the reference and regenerating watersheds. Mineral soil exchangeable calcium (Ca) and sodium (Na) concentrations and contents, effective cation exchange capacity (CEC), and base saturation were at least twice as high ($P = 0.05$) in the regenerating compared to the reference watershed or pre-harvest

conditions. Changes in the N and Mg pools indicate that atmospheric deposition may be a concern for Mg depletion and N saturation at this site. However, Ca depletion does not appear to be occurring at this site. Soil solution and stream nutrients were compared between the regenerating and reference watersheds. The soil solution base cation and inorganic anion concentrations were two to four times higher ($P = 0.05$) in the reference compared to the regenerating watershed. In addition, bicarbonate (HCO_3^-) accounted for 63% of the cation:anion balance in soil solution of the regenerating watershed, but less than 1% in the reference watershed ($P = 0.05$). Soil solution Ca^{2+} and Mg^{2+} concentrations at 50 cm depth in the regenerating watershed showed a linear decrease ($P = 0.05$) 10 to 17 years after regeneration, whereas the stream Ca^{2+} and Mg^{2+} concentrations showed a linear increase ($P = 0.05$) during that timeframe. No consistent temporal trends ($P > 0.05$) in stream Ca^{2+} and Mg^{2+} occurred in the reference watershed. Higher concentrations ($P = 0.05$) of soil air carbon dioxide (CO_2), soil solution dissolved inorganic C (DIC), and soil exchangeable Na, at or below 20 cm in the regenerating watershed suggest that these contrasting results were due to higher mineral weathering rates in the regenerating watershed. The soil elemental and exchangeable cation pools indicate that whole-tree harvesting may be a sustainable practice for at least one rotation. However, the soil solution and stream chemistry indicate that the regenerating watershed has not yet reached equilibrium for nutrient cycling.

McLaughlin, J.W. 2007. **Forest Soil and Water Program: Five year research strategy 2006-2011**. Ont. Min. Nat. Resour., Ont. For. Res. Inst. Sault Ste. Marie, ON. For. Res. Inf. Pap. No. 166. 30 p. + append.

This report represents a five-year research strategy for MNR's Forest Research and Development Section's Forest Soil and Water Research Program (FSWRP). Included are the program goals, research priorities, policy links, transfer plans, staffing needs, and partnerships. The FSWRP contributes to MNR's policy support using three major research themes: (1) riparian zone management, (2) silviculture and soils, and (3) climate change; all areas that the program has been addressing since 2002 and in which knowledge uncertainty is high. Planned 2006-2011 research efforts will continue to reduce uncertainties, specifically in relation to soil carbon and water cycling. Also, partnerships will be refined to address emerging issues such as peatland management (under the climate change theme) as well as to parameterize and validate a series of process-based carbon, nutrient, and water models to improve understanding of how soil carbon and water interactions affect forest and aquatic productivity to develop a measurable indicator for sustainable forest management. This five-year strategy was based on a synthesis of the results of a workshop titled *Integrating OMNR Research Priorities and Climate Change: Soil and Water Resources* held February 15 - 16, 2005 in Sault Ste. Marie, as well as new policy directions introduced since that workshop.

McLaughlin, J.W. 2009. **Boreal mixed-wood watershed riparian zone cation cycling during two contrasting climatic years**. *Soil Sci. Soc. Am. J.* 73(4): 1408-1418.

Riparian zones are key transfer points for water, alkalinity, and base cations from terrestrial to aquatic ecosystems. Base cation cycling in, and fluxes from, forested and alder swamp riparian zones were investigated for one climatically "normal" and one dry season. The soil extractable base cation pools and pH were higher in the alder riparian type. Combined measurements of litter, forest floor, mineral soil, and soil solution indicate that base cation uptake in both riparian zones occurs from the mineral soil. It is not known, however, whether uptake is from the upper (<20 cm) or deeper (>20 cm) mineral soil. Litter N, P, Ca, and Mg concentrations indicate that the forested riparian zone is more sensitive to base cation depletion than the alder riparian zone. Soil solution base cation concentrations in the forested riparian zone were attributed to Si mineral weathering and organic matter mineralization. In contrast, carbonate, probably calcite, weathering was more common in the alder riparian zone. Base cation stoichiometry was similar between years and riparian types, but the proportion of anions shifted to dominance by SO_4^{2-} and organic acids during fall of the drier year, which resulted in higher fluxes of those anions. The anion shifts, however, were not reflected in base cation fluxes. Uncertainties in shifts in litter quality, mineralization, and hydrologic flux in response to temperature and moisture change require further documentation to adequately deduce the role of such changes, along with rainfall amounts, on base cation cycling in riparian zones.

McLaughlin, J.W. 2010. **Climate change and peatland research project.** Ont. Min. Nat. Resour., Far North IKM Proj. Tech. Note No. IKMP-028. 9 p.

In this note, the author describes a research study underway to update estimates of peatland carbon storage and sequestration in the Hudson Bay Lowlands. Related information needs, general study approach, accomplishments to date, partners, and sub-studies are summarized briefly.

McLaughlin, J.A. and T. Hsiang. 2010. **Identification protocol for six *Armillaria* species from northeastern North America.** Can. J. For. Res. 40(3): 536-548.

DNA sequences (similar to 3 kb long) extending from the intergenic spacer 1 (IGS1) region to the 18S gene were obtained for isolates of *Armillaria ostoyae*, *Armillaria calvescens*, *Armillaria gallica*, and *Armillaria sinapina*. Additional investigation of 16 *A. ostoyae*, 11 *Armillaria gemina*, 21 *A. calvescens*, 18 *A. gallica*, and 15 *A. sinapina* isolates produced 117 sequences spanning the 3' end of the IGS1 through the 5S gene and into the 5' end of the IGS2 region. Additional sequences spanning the 3' IGS2 to 5' 18S gene region were obtained for two *A. ostoyae*, three *A. gemina*, two *A. calvescens*, two *A. gallica*, and three *A. sinapina* isolates. This is the first report of complete IGS2 sequences from *Armillaria* spp. A species identification protocol involving species-specific primers and restriction fragment length polymorphism analysis was devised based on species-specific polymorphisms. The protocol successfully identified all 16 *A. ostoyae*, 11 *A. gemina*, three of three *Armillaria mellea*, 18 *A. gallica*, 14 of 15 *A. sinapina* (11/12 diploid and 3/3 haploid), and 14 of 21 *A. calvescens* (13/15 diploid and 116 haploid) isolates included in this study. According to the authors, this success rate has not been matched by other methods.

McLaughlin, J.A., T. Hsiang, G. Halicki Hayden and S. Greifenhagen. 2010. **Mortality in southern Ontario red pine plantations: Causes, consequences, and management options.** Ont. Min. Nat. Resour., Ont. For. Res. Inst., Sault Ste. Marie, ON. For. Res. Note No. 69. 4 p.

Red pine plantations, common across southern Ontario, are showing signs of rapid decline and mortality. Researchers have found that plantations on sites with an alkaline C horizon are at high risk of damage from pathogens and insects. Shallower rooting on these sites makes trees more susceptible to drought stress, which acts as an *inciting factor* for decline by reducing their ability to defend themselves from attacks by root disease pathogens or insects such as bark beetles. Plantations established on sites with alkaline A and B soil horizons will likely decline very early (before the plantation reaches 40 years of age) due to iron deficiency, which will be more pronounced in dry years. Management recommendations for establishing and managing red pine plantations in southern Ontario are provided.

McLaughlin, J.W. and K.L. Webster. 2010. **Alkalinity and acidity cycling and fluxes in an intermediate fen peatland in northern Ontario.** Biogeochemistry 99(1-3): 143-155.

Peatlands are important to global carbon (C) sequestration and surface water acid-base status, both of which are affected by peatland alkalinity and acidity cycling. Relationships among sulfate (SO_4^{2-}), nitrate (NO_3^-), organic acids (OA^-), base cations (i.e., Ca^{2+} , Mg^{2+} , K^+ , and Na^+), proton (H^+) acidity, and bicarbonate (HCO_3^-) alkalinity were investigated in an intermediate fen peatland in northern Ontario during 2004 (an average precipitation year) and 2005 (a dry summer). Potential evapotranspiration was higher and the water table, groundwater input from the uplands, and runoff were lower during 2005. Net inputs of base cations, HCO_3^- , SO_4^{2-} , and OA^- , and to a lesser degree NO_3^- , were lower during the drier year, mainly due to lower groundwater transfer to the fen. Fen porewater HCO_3^- concentration and net output were also lower in the drier year, whereas Ca^{2+} , Mg^{2+} , and SO_4^{2-} concentrations and net output were higher. During the climatically average year, N immobilization, carbonic acid (H_2CO_3) dissociation, and OA dissociation were equally important H^+ -producing reactions. Peat cation exchange accounted for 50% of the H^+ sink, while SO_4^{2-} reduction and denitrification accounted for an additional 20 and 25% of the H^+ sink, respectively. During the dry year, S oxidation accounted for 55% of the H^+ net production, while that for H_2CO_3 dissociation was 70% lower than that during the climatically average year. Peat cation exchange consumed three times the acidity, and accounted for 92% of the H^+ consumption during the dry year compared to the climatically average year. This was consistent with a three-fold higher net base cation export from the fen during the dry year. Based on the study results, a conceptual model was developed that describes the role of acidity formation and its implications to intermediate fen acidification.

- McPherson, S., F.W. Bell, J. Leach, P. Street and A. Stinson. 2008. **Applying research for enhanced productivity on the Canadian Ecology Centre - Forestry Research Partnership forests.** *For. Chron.* 84(5): 653-665.

The application of enhanced forest productivity (EFP) through intensive silviculture on designated forest areas is arguably one means to maintain or increase fibre supply and global market competitiveness. The Canadian Ecology Centre-Forestry Research Partnership's (CEC-FRP) 10/10 objective (to increase sustainable fibre production by 10% in 10 years) has focused many years of forest research largely on the practical application of EFP. Large-scale implementation of this research, through a process of adaptive management, requires first identifying forests that are available and potentially suitable to implement EFP with more intensive silviculture on portions of the land base. In this paper, the authors describe forests in northeastern Ontario that were evaluated for EFP potential, and provide the rationale for their selection or rejection. The Gordon Cosens, Romeo Malette, Martel, and Nipissing forests were identified as potential CEC-FRP core forests in which research could be directed towards sustainable increases in forest production. These forests are located in Ontario's boreal and Great Lakes-St. Lawrence forest regions and have the necessary tenure, potential productivity, protection from fire, insects and disease, and are managed under a suitably enabling planning and legislative environment. In addition, forest management planning teams for these forests are closely integrated with the CEC-FRP through core teams that are critical to identifying science priorities based on local operational issues and moving subsequent research into practice. As such, it seems timely to move forward with EFP implementation through a process of adaptive management on these forests.

- Moorthy, I., J.R. Miller and T.L. Noland. 2008. **Estimating chlorophyll concentration in conifer needles with hyperspectral data: An assessment at the needle and canopy level.** *Remote Sens. Environ.* 112(6): 2824-2838.

This investigation quantitatively links chlorophyll *a+b* ($chl(a+b)$) concentration, a physiological marker of forest health condition, to hyperspectral observations of jack pine, a dominant boreal forest species. Compact Airborne Spectrographic Imager (CASI) observations, in the visible-near infrared domain, were acquired over eight selected jack pine sites, near Sudbury, Ontario, between June and September of 2001. Supplementing the airborne campaigns was concurrent on-site collection of foliage samples for laboratory spectral and chemical measurements. The study first connected needle-level optical properties with pigment concentration through the inversion of radiative transfer models, LIBERTY and PROSPECT. Next, a chlorophyll sensitive optical index ($R750/R710$) was "scaled-up" using SAILH, a turbid medium canopy model, to estimate total pigment content at the canopy-level. Due to the potential confounding effects of open canopy structure and foliage clumping, the analysis focused on high spatial resolution CASI imagery (1 m) to visually target tree crowns, while accounting for shadowed areas. $Chl(a+b)$ concentration estimation from airborne spectral data using coupled leaf and canopy models was shown to be feasible, with a root mean square error of $5.3 \mu g \cdot cm^{-2}$, for a pigment range of 25.7 to $45.9 \mu g \cdot cm^{-2}$. Such predictive algorithms using airborne-level data provide the methodology to be potentially scaled-up to satellite-level hyperspectral platforms for large-scale monitoring of vegetation productivity and forest stand condition.

- Newmaster, S.G., F.W. Bell, C. Roosenboom, H.A. Cole and W.D. Towill. 2006. **Restoration of floral diversity through plantations on abandoned agricultural land.** *Can. J. For. Res.* 36(5): 1218-1235.

Plantations have been claimed to be "monocultures" or "biological deserts". These claims were investigated in the context of a long-term study on plant diversity within plantations with different indigenous tree species, spacings, and soil types that were compared with 410 native stands. Soil type had no influence on plantation species diversity or abundance, and wider spacing resulted in higher richness, lower woody plant abundance, slightly higher cover of herbaceous plants, and large increases in cryptogam cover. Results showed a canopy species $\times$ spacing interaction effect, where the effect of increased spacing on understory vegetation was more pronounced in spruce than in pine plantations. The dynamic community interactions among species of feathermoss appear to be in response to the physical impediment from varying amounts of needle rain from the various tree species. High light interception and needle fall were negatively correlated with understory plant diversity, as was lack of structural diversity. The results indicated that afforestation efforts can restore agricultural lands to productive forests that can harbour nearly one-half of the plant species found in equivalent natural forests within the same geographic region in as little as 50 years. The authors recommended applying afforestation using indigenous conifer species as a first step towards rehabilitating conifer forests that have been converted to agriculture and subsequently abandoned.

Newmaster, S.G., W.C. Parker, F.W. Bell and J.M. Paterson. 2007. **Effects of forest floor disturbances by mechanical site preparation on floristic diversity in a central Ontario clearcut.** *For. Ecol. Manage.* 246(2-3): 196-207.

The effects of forest floor disturbance by six mechanical site preparation (MSP) treatments on structural and compositional diversity of early successional communities were examined in a clearcut in central Ontario. Floristic diversity and abundance were periodically assessed to quantify treatment effects on species richness and abundance of three discrete plant life forms (cryptogam, herbaceous and woody) in the first five growing seasons after MSP. Botanical surveys of the surrounding uncut forest provided an estimate of pre-harvest forest species composition of the study site. Intensity of forest floor disturbance differed significantly among MSP treatments, creating a variety of microsites. The percentage of mineral soil exposure and abundance of downed woody material ranged from 7% to 52% and 18% to 1%, respectively, from the least to most severe treatments. Five years after MSP, 134 species (50 cryptogams, 47 herbaceous, 37 woody) were present in the clearcut study site, compared with 102 species (54 cryptogams, 25 herbaceous, 23 woody) in the uncut forest. Species richness and abundance of cryptogam, herbaceous, and woody plant species increased with time after MSP, except for herbaceous species richness. MSP significantly influenced species richness of cryptogams, herbaceous, and woody plants, and abundance (percent cover) of woody plants. Treatment differences in richness and abundance were strongly correlated with intensity of forest floor disturbance. Scalping treatments that created the most mineral soil exposure and removed the most downed woody material typically resulted in areas with the lowest species diversity that lacked several native forest species. Cryptogams were most affected by MSP, with higher richness and abundance where forest floor disturbance was relatively low. MSP did not affect the incidence of alien plant species: only two alien species were observed on the study site, representing less than 1% of total cover. Evaluation of MSP effects on early successional plant communities based on beta diversity in an ordination analysis revealed several distinct species groups associated with specific treatments. The relative amount of forest floor disturbance and downed woody material among treatments were strong predictors of species groupings within the ordination. Examination of species' autecology provided supporting evidence that the displacement of downed woody material and forest floor organic layers was the leading cause of changes in species richness and abundance on this site.

Newton, P.F. and V.M. LeMay. 2007. **Complex stand structures and associated dynamics: Measurement indices and modelling approaches – Popular summaries.** Ont. Min. Nat. Resour., Ont. For. Res. Inst. Sault Ste. Marie, ON. For. Res. Inf. Pap. No. 167. 117 p.

Complex forest stands that have resulted from paradigm shifts in forest management practices (e.g., variable retention silvicultural systems, natural disturbance pattern emulation, systematic/selection mechanized thinning treatments) represent an increasing proportion of the productive forest land base throughout many of the world's forested ecosystems. Characterized by structural heterogeneity (e.g., multimodal diameter, height, and age distributions with aggregated and segregated spatial patterns), complex stands are intrinsically difficult to measure and model, particularly their structural attributes (e.g., size distributions and spatial patterns) and temporal dynamics (e.g., survivor growth, ingress (regeneration), mortality, succession vectors, and spatial dynamics). Thus, a conference, entitled *Complex Stand Structures and Associated Dynamics: Measurement Indices and Modelling Approaches*, was organized with the overall purpose of reviewing the latest measurement and modelling research pertaining to complex stand structures from a global perspective to benchmark the current state of knowledge, share successes, and compare various measurement and modelling approaches. The conference program included six plenary sessions, concurrent poster sessions, and a field tour to view some of the complex stand structures common to the Great Lakes-St. Lawrence forest region of central Canada. Plenary sessions consisted of a state-of-knowledge overview related to the session theme by an invited keynote speaker, followed by volunteer oral presentations. Sessions themes were: *Overview of Complex Stand Structures*, *Dynamics of Complex Stand Structures*, *Measuring Complexity I*, *Measuring Complexity II*, *Modelling Complexity*, and *Managing Complex Stand Structures: Economic Consequences, Operational Challenges, and Decision-support Tools*. This document provides a brief, detailed summary of each presentation in three-page popular summary format.

Newton, P.F. and M. Sharma 2008. **Evaluation of sampling design on taper equation performance in plantation-grown *Pinus banksiana*.** Scand. J. For. Res. 23(4): 358-370.

The objective of this study was to determine empirically the optimum disk selection protocol when calibrating (1) the dimensional compatible variable-exponent taper equation, (2) the segmented polynomial taper equation, and (3) the modified variable-exponent taper equation, for plantation-grown jack pine trees. The full data set, consisting of 187 trees randomly selected within 21 jack pine plantations situated within the Canadian boreal forest region, was randomly subdivided into calibration (parameterization) and validation (performance) subsets of approximately equal size. Based on prediction lack-of-fit indices (positional and tree-level absolute and relative mean biases in inside-bark diameter, cross-sectional area, and total stem volume), results indicated that the performance of the dimensional compatible and segmented equations was approximately equivalent among the 16 protocols evaluated (combinations of four above breast-height percentage-height sampling schemes with four below breast-height fixed-height sampling schemes). Conversely, the modified variable-exponent equation was strongly influenced by disk selection protocol, with the 10% sampling intensity combined with disks selected at 0.15, 0.5, 0.9 and 1.3 m found to be most efficient. In summary, the results of this study suggest that, when calibrated for plantation jack pine trees, the empirically derived modified variable-exponent equation was more data sensitive than the functionally derived dimensional compatible and segmented equations.

Noland, T.L., G. McVey and D. Chapeskie. 2006. **Ice storm and fertilization effects on root starch, sap productivity and sweetness, diameter growth, and tap hole closure in sugar maple stands of eastern Ontario.** Ont. Min. Nat. Resour., Ont. For. Res. Inst., Sault Ste. Marie, ON. For. Res. Note. No. 68. 6 p.

The effect of fertilizer was examined on 15 sugar maple stands in eastern Ontario managed for syrup production that sustained 7% to 72% ice-induced crown damage. Stands were divided into four plots that received the following fertilizer treatments: dolomitic lime calcium (Ca) and magnesium (Mg), phosphorous (P) and potassium (K), lime plus P+K treatments, and no fertilizer in June 1999. The effects of crown damage level and fertilization on root starch, sap volume, sap sugar content, syrup production, and tap hole closure rate were examined during Phase I of this study, which ran from 1998 to 2001. During Phase II, fall root starch content and stem diameter growth (fall of 2003), sap volume and sugar content, hourly block temperatures measured during the sap run (spring of 2004), and tap hole closure (fall of 2004) were examined and effects on syrup production calculated. Fall root starch content, sap volume, and tap hole closure rate were not affected by crown damage level. Sugar content of sap was reduced in trees with moderate (26-50%) and severe (>50%) damage. Moderate damage also lowered syrup production per tap. Daily air temperature amplitudes were about 1°C greater in moderately and severely damaged compared to lightly (0-25%) damaged stands. Moderately and severely damaged trees also had less stem diameter growth in 1999 through 2001, but not in 2002 and 2003. The fertilizer and lime treatments had no significant effects. Results suggest that ice storm damage to crowns significantly affects sap sweetness and syrup production capacity of sugar maple for up to six years.

Noland, T.L., W.C. Parker and A.E. Morneau. 2006. **Natural variation in seed characteristics of eastern white pine (*Pinus strobus* L.).** New For. 32(1): 87-103.

Natural variation in seed characteristics of eastern white pine trees and its relationship with the size, form, and crown class of parent trees was examined in second-growth, white pine mixedwood stands in Ontario. Cones were collected prior to and following partial harvesting of two stands during two years of above-average seed production. Fully enlarged seed extracted from mature cones was x-rayed to determine seed yield per cone, the percentage of sound, partially filled, and empty seed, and the sound seed mass for each tree. Variation in seed yield per cone, the proportion of sound, partially filled, and empty seed, and seed mass was much greater among individuals than between stands or seed years. The strength and significance of the relationship of seed mass with sound seed yield differed with stand and seed year. In uncut stands, seed mass was higher for trees with dominant crown class, larger live crown ratios, and smaller height to diameter ratios, suggesting tree vigour and microsite quality influence seed mass. Proportion of partially filled seeds was significantly reduced in both stands in the second year, likely due to increased growing degree days during female gametophyte development. The implications of these results to natural and artificial regeneration of white pine are discussed.

Noland, T. and M. Abou-Zaid. 2008. **Canada yew: Developing a value-added crop for northern Ontario.** Ont. Min. Nat. Resour., Ont. For. Res. Inst., Sault Ste. Marie, ON. For. Res. Inf. Pap. No. 172. 19 p. + append.

Canada yew is a native evergreen shrub found in most of Ontario that contains anticancer compounds called taxanes in its needles, bark, and roots. In 2004, a research project was initiated to (i) develop methods for selecting individual yew plants with high growth rates and high taxane concentrations, and (ii) determine the best methods for growing Canada yew in plantations, towards the goal of developing the capacity to produce a commercially viable yew crop in northern Ontario. Four plantations were established in the Algoma district of Ontario: one in June 2004 at the Ontario Forest Research Institute (OFRI) arboretum and three in late August 2005 at the OFRI arboretum, Thessalon First Nation BioCentre, and Whelan farm. Treatments imposed on all the plantations were (1) crop plant spacing at 30 and 45 cm, (2) soil treatments of mulch, fertilization, and mulch-plus-fertilization. Compost and mulch-plus-compost treatments were applied only to the 2004 plantation. Compared to the controls, only the 2004 plantation showed significant treatment-related increases in growth in all but the spacing treatments, with fertilization and mulch-plus-compost resulting in about 15 to 50% more growth, respectively, than the other treatments. Fertilization provided the most cost effective increase in yew plantation growth. Deer browsed the plants at all sites and, of the three herbivore control measures attempted, only the electric fence successfully excluded deer. Selection of individual yew plants for high growth rates and taxane concentrations yielded individuals with three to four times the potential taxane production capacity of the average plant. Further development of Canada yew as a value-added crop will require these high taxane-producing individuals to be propagated for plantation culture.

Noland, T.L. and M. Abou-Zaid. 2009. **Growing Canada yew in plantations: Profitable or not?** *Silvic. Mag.*: 10-12. Brief article on the economics of growing Canada yew in plantations.

Obenchain, A.M., ed. 2006. **Insights.** Ont. Min. Nat. Resour., Ont. For. Res. Inst., Sault Ste. Marie, ON. 7(2): 20.

This issue of OFRI's newsletter presents articles on results of a workshop on improving wood supply estimates, overviews of research projects including using stem profile models in the softwood lumber negotiations, controlling vegetation to promote aspen and spruce, using forest management to store more carbon in Ontario's forests, protecting investments in long-term hardwood research, using large-scale photography in Great Lakes-St. Lawrence forest inventory, partial harvesting in old growth white pine, developing blister rust-resistant white pine, protecting MNR's genetic archives, stemming red pine decline in southern Ontario, identifying tree fungi using DNA, understanding forest tent caterpillar defoliation and aspen stand dynamics, and using biomass for biofuels in a way that improves silviculture, and summaries of publications about transferring information about regenerating forests, estimating tree decay, as well as a profile of research scientist Bill Cole, facts about OFRI, and OFRI forest research trivia.

Obenchain, A.M., ed. 2007. **Insights.** Ont. Min. Nat. Resour., Ont. For. Res. Inst., Sault Ste. Marie, ON. 8(1): 20.

This issue of OFRI's research newsletter presents articles on the amount of carbon stored in wood products, Ontario's future climate, understanding fire regimes, soil and water research update, new soil-water research strategy, using peat for fuel, industry using NEBIE framework, improving wood supply predictions, air- vs. ground-based FRI data, white pine seed research results, ten year results of vegetation management studies, test results of a pill to improve white pine survival, updated on bioindicators of forest condition research, stem profile model news, and ice damage work wrap up, as well as a profile of research scientist Jim McLaughlin, staff news, ask the expert, upcoming events, and OFRI research trivia

Obenchain, A., ed. 2008. **Insights.** Ont. Min. Nat. Resour., Ont. For. Res. Inst., Sault Ste. Marie, ON 8(2): 12.

This issue of OFRI's research newsletter presents articles on release of the BFOLDS simulation model, saving butternut, red oak shelterwoods, converting red pine plantations, frost damage and climate change, carbon storage, OFRI's arboretum, boreal plantation diversity, workshops, as well as a profile of a forester intern, staff news, ask the expert, upcoming events, and OFRI research trivia

Obenchain, A., ed. 2008. **Insights Express**. Ont. Min. Nat. Resour., Ont. For. Res. Inst., Sault Ste. Marie, ON March 2008: 4 p.

This interim issue of OFRI's Insights newsletter presents highlights of several research projects: light levels in stands harvested using MNR's natural disturbance emulation guide, effect of stand density on tree form, restoring butternut to southcentral Ontario, what is known about what fire leaves behind, and overviews of three workshops: managing tree seed under climate change, modelling complex stands, and *Science Matters V*.

Obenchain, A., ed. 2009. **Insights**. Ont. Min. Nat. Resour., Ont. For. Res. Inst., Sault Ste. Marie, ON 9(1): 12.

This issue of OFRI's research newsletter presents articles on somatic embryogenesis, Canada yew, boreal mixedwood research, white pine in northeastern Ontario, fire regime research results, biomass harvesting, Far North carbon and peatland research, afforestation to store carbon, a staff profile, staff news, and ask the expert column.

Obenchain, A., ed. 2010. **Insights**. Ont. Min. Nat. Resour., Ont. For. Res. Inst. 10(1): 16.

This issue of OFRI's research newsletter presents articles on plant diversity research, growth and yield modelling update, climate and nutrient cycling, diagnosing tree diseases, red pine decline, 20 years of research highlights, eastern white cedar research, vegetation management advances, human activities and caribou forage, effects of climate on parks and tree species migration, a tool to capture succession knowledge, a staff profile, staff news, and ask the expert column.

Ouellette, M. 2008. **BFOLDS 1.0: A user's guide to the software package (Version 1.0.0)**. Ont. Min. Nat. Resour., Ont. For. Res. Inst. Sault Ste. Marie, ON. For. Res. Inf. Pap. No. 171. 68 p.

This report provides instructions for accessing and using the Boreal Forest Landscape Dynamics Simulator – BFOLDS 1.0.

Ouellette, M.R. and M. Drescher. 2010. **Succession Pathway Tool 1.0: user's guide**. Ont. Min. Nat. Resour., Ont. For. Res. Inst. Sault Ste. Marie, ON. For. Res. Inf. Pap. No. 173. 39 p. + append.

Forest succession knowledge is used extensively to support forest management decisions. However, that knowledge is often implicit and thus not documented or transferable. The Succession Pathway Tool (SPT) is a software package for Windows designed to help users of succession knowledge make their knowledge of forest succession explicit, visualize it using networks, and explore its emerging properties using stochastic aspatial simulations. The tool also provides a means to document and share forest succession knowledge. Here the software tool is introduced to prospective users and step-by-step instructions are provided along with a brief tutorial with examples of its application. Information about how to export documented succession knowledge for use in other tools, including the Boreal Forest Landscape Dynamics Simulator (BFOLDS), is also provided.

Parker, W.C., T.L. Noland and A.E. Morneau. 2006. **The effects of seed mass on germination, seedling emergence, and early seedling growth of eastern white pine (*Pinus strobus* L.)**. New For. 32(1): 33-49.

Half-sib seed of several eastern white pine families was used to examine seed mass effects on laboratory germination and seedling emergence and growth under moderate and low light (47 and 13% full sunlight) in a greenhouse. Percent germination and speed of germination under laboratory conditions were not related to seed mass among half-sib families or multi-family seedlots bulked by seed mass. Percent seedling emergence in the greenhouse was not related to seed mass, but emergence was faster for families with heavier seeds. Both rate and percent emergence were significantly increased under low light. Family differences in leaf, stem, root, and total seedling dry mass, primary root length, and the number of first-order lateral roots were positively related to seed mass in both light environments. Low light diminished the absolute biomass increment per unit seed mass, but the proportional change in biomass with seed mass was similar between light environments. Rate of emergence also influenced seedling size within families, with earlier emergence increasing seedling dry mass from 7 to 58%, depending on light environment. Biomass partitioning coefficients were influenced by light environment but largely independent of seed mass.

Parker, W.C. and D.C. Dey. 2008. **Influence of overstory density on ecophysiology of red oak (*Quercus rubra*) and sugar maple (*Acer saccharum*) seedlings in central Ontario shelterwoods.** Tree Physiol. 28(5): 797-804.

A field experiment was established in a second-growth hardwood forest dominated by red oak to examine the effects of shelterwood overstory density on leaf gas exchange and seedling water status of planted red oak, naturally regenerated red oak, and sugar maple seedlings during the first growing season following harvest. Canopy cover of uncut control stands and moderate and light shelterwoods averaged 97, 80, and 49%, respectively. Understory light and vapour pressure deficit (VPD) strongly influenced gas exchange responses to overstory reduction. Increased irradiance beneath the shelterwoods significantly increased net photosynthesis (P-n) and leaf conductance to water vapour (G(wv)) of red oak and maple seedlings; however, P-n and G(wv) of planted and naturally regenerated red oak seedlings were two to three times higher than those of sugar maple seedlings in both partial harvest treatments, due in large part to decreased stomatal limitation of gas exchange in red oak due to increased VPD in the shelterwoods. In both species, seedling water status was higher in the partial harvest treatments, as reflected by the higher predawn leaf water potential and seedling water-use efficiency in seedlings in shelterwoods than in uncut stands. Within a treatment, planted and natural red oak seedlings exhibited similar leaf gas exchange rates and water status, indicating little adverse physiological effect of transplanting. The authors concluded that the use of shelterwoods favours photosynthetic potential of red oak over sugar maple, and should improve red oak regeneration in Ontario.

Parker, W.C., K.A. Elliott, D.C. Dey and E. Boysen. 2008. **Restoring southern Ontario forests by managing succession in conifer plantations.** For. Chron. 84(1): 83-94.

Thinning and underplanting of conifer plantations to promote natural succession in southern Ontario's forests for restoration purposes was examined in a young red pine plantation. Eleven years after application of five thinning treatments, seedling diameter, height, and stem volume of planted white ash, red oak, and white pine were positively correlated with thinning intensity and size of canopy openings. Percent survival did not differ among thinning treatments. Based on growth and survival responses, field performance of white ash and white pine was superior to red oak. Recommendations for restoring conifer plantations to native forest types are provided.

Parker, B. 2009. **The role of planted forests in climate action.** Silv. Mag. 8-11.

Brief magazine article highlighting the potential for plantations to be used to mitigate climate change.

Parker, W.C., G. Nielsen, J. Gleeson and R. Keen. 2009. **Forecasting carbon storage and carbon offsets for southern Ontario afforestation projects: The 50 million tree planting program.** Ont. Min. Nat. Resour., Appl. Res. Devel. Br. Sault Ste. Marie, ON. Climate Change Res. Rep. CCRN-10. 8 p.

International efforts aimed at addressing climate change recognize afforestation as a relatively low cost option to enhance terrestrial carbon (C) storage, slow the rate of atmospheric carbon dioxide (CO₂) accumulation, and mitigate the adverse effects of climate change. Creation of new forests is a key component of the Ontario government's climate change action plan to reduce provincial emissions of greenhouse gases. The province recently committed to planting 50 million trees on about 25,000 hectares in southern Ontario between 2008 and 2020. Planting of red pine and/or white spruce in this afforestation effort is projected to store between 0.5 to 3.6 Mt C in living tree biomass and remove 1.7 to 13.3 Mt CO₂ from the atmosphere by 2050, depending on site and soil characteristics and the level of management applied. Afforestation will be centred on private land in the southern region of the province where most of the 1.26 million hectares of marginal or fallow agricultural land that is potentially available for tree planting is located. Designing afforestation programs that provide appropriate incentives to increase the participation of private landowners in tree planting can increase the total area planted, the amount of C stored, and the relative contribution of tree planting in meeting provincial greenhouse gas emissions reduction targets.

- Parker, W.C., D.G. Pitt and A.E. Morneau. 2009. **Influence of woody and herbaceous competition on microclimate and growth of eastern white pine (*Pinus strobus* L.) seedlings planted in a central Ontario clearcut.** For. Ecol. Manage. 258(9): 2013-2025.

The influence of woody and herbaceous plant competition, either alone or in combination, on microclimate and growth of planted eastern white pine seedlings was examined over four consecutive growing seasons in a central Ontario clearcut. Treatments that manipulated the comparative abundance of these two plant functional groups significantly affected light availability, soil moisture, and air and soil temperature regimes. These microclimate alterations, coupled with the relative competitiveness of herbaceous and woody vegetation, corresponded to temporal changes in vegetation cover and dominance. The more rapid colonization and growth of the herbaceous plant community, dominated by bracken fern and ericaceous shrubs, resulted in this form of vegetation being a comparatively important early competitor for soil moisture. As the woody plant community, dominated by naturally regenerated trembling aspen, grew in height and leaf area, it became a comparatively strong competitor for both light and soil moisture. For all vegetation treatments combined, white pine seedling growth responses were strongly correlated with total cover of competing vegetation and its relative influence on above- and belowground microclimatic variables. Higher total cover of competing vegetation was generally associated with lower light and soil moisture availability and cooler soil temperatures. Multiple regression analyses indicated that pine seedling relative height growth increased with soil moisture content and growing season soil heat sum while seedling relative diameter and relative volume growth increased with light availability.

- Parker, W.C., T.L. Noland and B. Brown. 2010. **Effects of structural retention harvesting on seed production and seed characteristics of old-growth eastern white pine (*Pinus strobus* L.) stands in northern Ontario.** For. Chron. 86(5): 614-622.

Seed production and seed characteristics were examined during a mast seeding year in unmanaged, old-growth eastern white pine stands located in northeastern Ontario and compared with those in adjacent stands partially harvested 16 years earlier using a structural retention system. Seed yields from old-growth stands were comparable to those of mature, second growth white pine stands but seed production assessed relative to unit area and pine basal area was lower in partially harvested stands. In both unmanaged and harvested stands, seed production rate of trees growing in localized areas of lower pine basal area was higher. Seed characteristics and seed viability did not differ between harvest treatments. Although structural retention harvesting reduced seed production, results suggest that supply and viability of seed are unlikely to limit seedling recruitment in managed or protected old-growth white pine forests.

- Parker, W.C., D.G. Pitt and A.E. Morneau. 2010. **Influence of woody and herbaceous vegetation control on leaf gas exchange, water status, and nutrient relations of eastern white pine (*Pinus strobus* L.) seedlings planted in a central Ontario clearcut.** For. Ecol. Manage. 260(11): 2012-2022.

The influence of herbaceous and woody vegetation control, either singly or in combination, on leaf gas exchange, water status, and nutrient relations of planted eastern white pine seedlings was examined in a central Ontario clearcut over four consecutive growing seasons (GSs). Net carbon assimilation ($A(n)$), leaf conductance to water vapour ($G(wv)$), water use efficiency (WUE), and midday leaf water potential ($\psi(m)$) were measured periodically during the second to fourth GSs of vegetation control treatments, while leaf nutrient relations were examined in GS five. Leaf $A(n)$ and $G(wv)$ were reduced ($p \leq 0.05$) in the presence of herbaceous vegetation in GS two, by both herbaceous and woody vegetation in GS three, and only by woody vegetation (largely trembling aspen) in GS four. Leaf WUE was increased ($p \leq 0.05$) in all three GSs in which herbaceous vegetation control was applied and where woody vegetation provided partial shading of planted white pine. Leaf water status was comparatively less responsive to vegetation control treatments, but leaf $\psi(m)$ was increased ($p \leq 0.05$) in the presence of woody vegetation in GSs two and four, likely due to shading and reduced atmospheric evaporative demand of the white pine seedling environment. Within a given GS, the effects of vegetation control on $A(n)$, $G(wv)$ and $\psi(m)$ were strongly linked to treatment-induced changes in total vegetative cover, and light and soil moisture availability. Seedling height, diameter, and volume growth rates were positively correlated with $A(n)$ and WUE in GSs two and three, but less so in GS four. Vector analysis suggested that herbaceous competition induced foliar N, P, and K deficiencies in five-year-old white pine seedlings while competition from aspen resulted in foliar Ca deficiency.

Perera, A.H. and L.J. Buse. 2006. **Multiple-scale research studies on boreal forest fire regimes to inform Ontario's policies for emulating natural forest disturbances: A prospectus.** Ont. Min. Nat. Resour., Ont. For. Res. Inst., Sault Ste. Marie, ON. For. Res. Inf. Pap. No. 164. 24 p. + append.

A clear understanding of forest fire regimes is essential for emulating natural disturbances in forest management. This prospectus presents a broad framework for a series of research studies to investigate Ontario boreal forest fire regime at multiple scales. The broad research goal is to reduce uncertainties in knowledge about boreal forest fire regimes related to policy directions in MNR's *Forest Management Guide for Natural Disturbance Pattern Emulation* (NDPE). This goal will be accomplished via establishing the state of the knowledge by reviewing and synthesizing published literature, determining the characteristics of the broad-scale fire regime in boreal Ontario through simulation modelling, and understanding the extent and spatial patterns of post-fire residuals using mapping and monitoring. In addition to reducing scientific uncertainties in NDPE guide directions, these studies will advance knowledge to inform future forest management policies and practices as well as other research on forest fires and emulating natural disturbances.

Perera, A.H., L.J. Buse and T.R. Crow (eds.). 2006. **Forest Landscape Ecology: Transferring Knowledge to Practice.** Springer, New York, NY.

The discipline of landscape ecology has matured rapidly over the past few decades, generating a wealth of knowledge that can be used to enhance forest policy development and management. However, much of this knowledge has yet to be applied in practice. *Forest Landscape Ecology: Transferring Knowledge to Practice* is the first book to introduce landscape ecologists to the discipline of knowledge transfer. The book considers knowledge transfer in general, critically examines aspects of transfer that are unique to forest landscape ecology, and reviews several case studies of successful applications for policy developers and forest managers in North America. Readers are encouraged to recognize the value of sharing their knowledge, and to understand their role in active knowledge transfer. The intent is to connect, as seamlessly and effectively as possible, ecological principles to policy and practice.

Perera, A.H., L.J. Buse and T.R. Crow. 2006. **Knowledge transfer in forest landscape ecology: A primer.** Pp. 1-18 in A.H. Perera, L.J. Buse and T.R. Crow (eds.). *Forest Landscape Ecology: Transferring Knowledge to Practice.* Springer. New York, NY.

The discipline of forest landscape ecology is maturing and the associated knowledge base is rapidly expanding. To ensure appropriate application of this accumulating knowledge in forest management, landscape ecologists need to become familiar with knowledge transfer, which is a process in which developers interact with users and make them aware of the available knowledge and its appropriate use. In this book chapter, the authors introduce the concept and importance of knowledge transfer to forest landscape ecologists, outline some of the factors that may influence its success, and explore what landscape ecologists can do to move their field of study from the abstract to an applied discipline.

Perera, A.H., L.J. Buse and R.G. Routledge. 2007. **A review of published knowledge on post-fire residuals relevant to Ontario's policy directions for emulating natural disturbance.** Ont. Min. Nat. Resour., Ont. For. Res. Inst. Sault Ste. Marie, ON. For. Res. Inf. Pap. No. 168. 37 p. + append.

This review of the literature is focused on establishing the state of knowledge on post-fire residuals as relevant to directions in Ontario's *Forest Management Guide for Natural Disturbance Pattern Emulation*. The post-fire residuals addressed here include live residuals (patches of live trees and individual live trees) as well as dead residual structure (snags and downed wood) remaining following forest fires. The authors review the descriptions, definitions and classification of residuals; estimates of their abundance and variability; and their spatial associations and temporal trends as reported for boreal North America, captured from reports that are published and universally accessible. Overall, the body of literature is relatively rich in terms of the number of publications that report estimates of abundance and extent of post-fire residuals. However, because the approaches used in defining and quantifying residuals are inconsistent, and sometimes ambiguous, it is difficult to synthesize and generalize this information. Furthermore, information on methods and results, which is critical to determine general patterns and trends in residuals, is relatively poor. Therefore, it is

difficult to synthesize the published knowledge and generalize on abundance and variability of post-fire residuals, especially in relation to causal mechanisms, spatial associations, and temporal changes. While this is the largest gap in published knowledge of post-fire residuals, it is also the area of scientific knowledge most required for translating broad forest policies for emulating natural disturbances into specific forest management directions and practices.

- Perera, A.H., L.J. Buse, R.G. Routledge, B.D. Dalziel and T. Smith. 2008. **An assessment of tree, snag, and downed wood residuals in boreal fires in relation to Ontario's policy directions for emulating natural forest disturbance.** Ont. Min. Nat. Resour., Ont. For. Res. Inst. Sault Ste. Marie, ON. For. Res. Rep. No. 168. 59 p. + append.

This study focused on assessing abundance, spatio-temporal variability, and causal factors of post-fire residuals as relevant to directions in Ontario's *Forest Management Guide for Natural Disturbance Pattern Emulation* (NDPE guide). The authors assessed residual trees, snags, and downed wood in 11 fires from three ecoregions in boreal Ontario using high-resolution airborne photographs (660 plots) as well as field samples (50 plots). Photo-plots were used to assess the abundance of residuals and field plots were used to quantify photo interpretation error as well as to monitor residual dynamics over three years. Abundance of residuals immediately post-fire, in all categories, varied widely both within and among fires. Occurrence of residual trees was spatially sporadic while snags were omni present. Expected residual tree abundance was considerably lower than that for snags. However, abundance of residual trees changed rapidly, with most changes occurring between the first and second year after fire. Due to residual tree mortality, the complement of snag and downed wood residuals increased in time. After three years, abundance of large diameter residual trees was very low, and congruent with directions provided in the NDPE guide for retaining residual trees post-harvest. Local fire intensity appeared to be the most important global determinant of occurrence of residual trees, but with an inverse relationship. Our results do not support the hypotheses that pre-burn forest cover and site conditions are reliable global predictors of residual tree occurrence.

- Perera, A.H., M. Ouellette, W. Cui, M. Drescher and D. Boychuck. 2008. **BFOLDS 1.0: A spatial simulation model for exploring large scale fire regimes and succession in boreal forest landscapes.** Ont. Min. Nat. Resour., Ont. For. Res. Inst., Sault Ste. Marie, ON. For. Res. Rep. No. 152. 50 p.

Boreal forest landscape dynamics simulator (BFOLDS) is a fire regime-succession simulation model that can be used to explore long-term forest cover changes at large spatial extents. This report documents BFOLDS' structure, components, assumptions, functionality, and applications. An appended user manual provides instructions for using BFOLDS 1.0, the graphics user interface-based software package that contains the simulation model. BFOLDS abstracts forest fire and succession processes quantitatively and stochastically in a spatially explicit manner. It logically combines fire ignition, growth, and extinguishment with forest succession based on input data of weather, forest composition, terrain, and soil. Simulation of these processes is accomplished by two interacting components: a fire simulation module and a forest succession module. The fire simulation module is process-based and primarily founded on published fire science knowledge of Canadian Forest Fire Behaviour Prediction System and Fire Weather Index system and consists of sub-modules for ignition, spread, and extinguishment of simulated fire events. The forest succession module is empirically based, and driven by a time-dependent Markov model, populated by user-input rules on forest cover transitions specific to a hierarchy of site conditions. BFOLDS is a raster-based model, operating at one hectare spatial resolution. Its temporal resolution varies from a day to a year, depending on the simulated process. BFOLDS is designed to discover characteristics of large scale boreal fire regimes, as emerging properties of synthesized knowledge and assumptions of weather, fire behaviour, forest fuel, and forest succession. Thus model users have opportunities to examine effects of their assumptions and input data on characteristics of simulated fire regime. These simulated scenarios of forest landscape dynamics are not meant to reflect the past, present, or future, but are a set of hypotheses extended based on model logic, assumptions, and input. BFOLDS is recommended for use in exploring the spatio-temporal variability in boreal forest fire regime based on what-if scenarios and assumptions as a research tool and to inform strategic applications of designing forest land use plans and developing forest policy.

Perera, A.H., W. Cui and M.R. Ouellette. 2009. **Size class distribution and spatial proximity of fires in a simulated boreal forest fire regime in relation to Ontario's policy directions for emulating natural disturbance.** Ont. Min. Nat. Resour., Ont. For. Res. Inst. Sault Ste. Marie, ON. For. Res. Rep. No. 170. 29 p.

This study focused on assessing distribution of fire sizes and their spatial proximity of occurrence as relevant to directions in Ontario's *Forest Management Guide for Natural Disturbance Pattern Emulation* (NDPE guide). Given the many inadequacies of estimating fire regime characteristics by empirical data of fire history, a simulation modelling approach was used for this assessment. BFOLDS, which models fire disturbances mechanistically and forest succession empirically, was used to simulate fire regime scenarios for boreal Ontario. Study area encompassed the ecoregions 3E, 3W, 3S, 4W, and 4S, in which fire regimes were simulated for 200 years. The authors used three potential fire weather scenarios – normal, cold, and warm – and two possible lightning patterns – random and biased – as model assumptions to address uncertainties in knowledge of long-term climate and weather patterns. All simulation scenarios were replicated to capture stochastic variability that emerges during modelling. From these results, fire size distributions and probabilities of spatial occurrence of fires were extracted for each simulation scenario. Fire size distribution varied significantly among ecoregions: some were characterized by relatively few small fires while others were dominated by many large fires. Effects of weather scenarios and lightning patterns were not consistent: in some ecoregions significantly higher number of larger fires resulted under the warm fire weather scenario than the cold, and for biased lightning pattern than the random; in others differences were not significant. Spatial proximity of fire occurrence varied significantly among all ecoregions, as well as the fire weather scenarios, but not between the ignition patterns. Overall, more fires occurred in the proximity of others under warm fire weather. The NDPE guide's direction for forest harvest sizes matched the simulated fire size distribution in only two ecoregions, under specific fire weather and lightning pattern scenarios. The guide's direction overestimated the fire size distribution in the same two ecoregions under other specific weather-lightning pattern scenarios. In the other three ecoregions, it underestimated fire size distribution under all simulation scenarios. The guide's direction for spatial proximity was not congruent with results from any simulated scenario in any ecoregion. However, the probability of spatial proximity was low in all but one ecoregion. In addition to the assessment of NDPE guide's direction, this study demonstrates that fire size distributions appear to be unique to ecoregions, and these can vary further if the fire weather conditions change.

Perera, A.H., B.D. Dalziel, L.J. Buse and R.G. Routledge. 2009. **Spatial variability of stand-scale residuals in Ontario's boreal forest fires.** Can. J. For. Res. 39(5): 945-961.

Knowledge of post-fire residuals in boreal forest landscapes is increasingly important for ecological applications and forest management. While many studies provide useful insight, knowledge of stand-scale post-fire residual occurrence and variability remains fragmented and untested as formal hypotheses. The authors examined the spatial variability of stand-scale post-fire residuals in boreal forests and tested hypotheses of their spatial associations. Based on the literature, they hypothesized that pre-burn forest cover characteristics, site conditions, proximity to water and fire edge, and local fire intensity influence the spatial variability of post-fire residuals. To test these hypotheses, they studied live tree and snag residuals in 11 boreal Ontario forest fires, using 660 sample points based on high resolution photography (1:408) captured immediately after the fires. The abundance of residuals varied considerably within and among these fires, precluding attempts to generalize estimates. Based on a linear mixed-effects model, our data did not support the hypotheses that pre-burn forest cover characteristics, site conditions, and proximity to water significantly affect the spatial variability of stand-scale residuals. The results do indicate, however, that stand-scale residual variability is associated with local fire intensity (strongly) and distance to fire edge (weakly).

Perera, A.H., T.K. Rimmel, L.J. Buse and M.R. Ouellette. 2009. **An assessment of residual patches in boreal fires in relation to Ontario's policy directions for emulating natural disturbance.** Ont. Min. Nat. Resour., Ont. For. Res. Inst., Sault Ste. Marie, ON. For. Res. Rep. No. 169. 65 p. + append.

This study focused on assessing extent and variability of post-fire residual patches as relevant to directions in Ontario's *Forest Management Guide for Natural Disturbance Pattern Emulation* (NDPE guide). The authors mapped 17 unsuppressed natural fires from northern boreal Ontario using IKONOS high resolution imagery. Satellite images were classified to identify burned as well as unburned land cover categories, and

fire perimeters were derived using a fuzzy logic mapping technique. Residual areas in study fires were delineated using definitions for insular patches and peninsular patches as outlined in the NDPE guide. Extent of both residual types varied widely among the fires, and large fires contained more patches and higher patch extent. Most insular patches were very small, more common in fire interiors, and appeared to be proximal to natural firebreaks. Insular patches were composed mainly of coniferous forest, shrubs, and wetland. Peninsular patch extent also varied widely among fires, with larger fires containing more patches, but not necessarily higher patch extent. No distinct spatial patterns of peninsular patches were associated with either fire geometry or natural fire barriers. These patches also were composed of coniferous forest, shrubs, and wetland. The NDPE guide direction's range for insular patch extent was well within the variability observed in our study fires, but overestimated the expected values in natural fires. The directions for spatial distribution of insular patches also matched the patterns observed within study fires. The NDPE guide direction's range for peninsular patch extent was well below the variability observed in the study fires, and greatly underestimated the expected values in natural fires. As well, the size threshold for insular patches that is imposed by the NDPE guide ignores a vast number of small patches, and thereby much of the extent of insular patch area that occurs in natural fires.

Perera, A.H. and W.B. Cui. 2010. **Emulating natural disturbances as a forest management goal: Lessons from fire regime simulations.** For. Ecol. Manage. 259(7): 1328-1337.

The major goal of this study was to demonstrate the utility of fire regime simulation modelling to explore the variability of fire regime characteristics, with respect to formulating and assessing forest management strategies. A modelling experiment was conducted in a boreal forest landscape of northwestern Ontario, Canada, to examine its long-term fire regime in relation to forest policies on harvest size distribution. BFOLDS, a spatially explicit fire regime model that simulates individual fire events mechanistically in response to fire weather, fuel patterns, and terrain, was used. The fire regimes in four large eco-regions were modelled for a 200-year period under three fire-weather (cold, normal, and warm) scenarios, with replications. Fire size distribution in all eco-regions followed power law under all weather scenarios, but their slopes and intercepts varied among eco-regions and fire weather scenarios. Warming fire weather increased burn rates and fire numbers in all eco-regions, albeit to different degrees. Overall, the variability among eco-regions was higher than the variability among fire weather scenarios, and among replicates. Comparisons of simulated fire size classes with those from an 86-year fire history showed that empirical data cannot capture the variability that could be revealed by simulation modelling. The authors also show that fire size distribution is spatially heterogeneous within eco-regions, and provide several suggestions for forest policy directions with respect to forest harvest size distributions and harvest rates, based on the variability of fire regime characteristics. An assessment of present forest policies of emulating natural disturbances that guide forest harvest sizes showed that these are incongruent with simulated fire size distributions under all scenarios with one exception. Overall, this study illustrates the value of scenario simulation modelling to explore and quantify the variability of forest fire regime, for use in forest policies and strategies that attempt to emulate natural disturbance.

Pinto, F., D. Rouillard, J.M. Sobze and M. Ter-Mikaelian. 2007. **Validating tree species composition in forest resource inventory for Nipissing Forest, Ontario, Canada.** For. Chron. 83(2): 247-251.

Species composition estimated from forest resource inventory (FRI) was validated using field data collected in 136 stands in Nipissing Forest (Ontario, Canada). FRI- and field-based species composition matched in 54% and 56% of cases using stand count and area coverage, respectively. Possible causes of discrepancy between FRI- and field-based species composition are discussed. Low level of agreement between FRI and field data indicated a need for more extensive studies on FRI validation prior to its use for forest management planning.

Pinto, F., M. Ter-Mikaelian, J.-M. Sobze and D. Rouillard. 2007. **A method to validate stand attributes in a forest resource inventory: Case study in Nipissing Forest, Ontario.** Ont. Min. Nat. Resour., Ont. For. Res. Inst. Sault Ste. Marie, ON. For. Res. Rep. No. 166. 10 p. + append.

Stand attributes estimated from forest resource inventory (FRI) were validated using field data collected in 136 stands in Nipissing Forest (Ontario, Canada). The results showed 39% agreement between

classification of stands into standard forest units (SFU) based on comparing FRI- and field-estimated species composition. Stand age, height, and stocking were compared separately for groups of stands representing seven standard forest units, classified based on FRI species composition. The FRI-based stand age was on average 20 years greater than that estimated in the field for three of the standard forest units compared but no significant difference between FRI- and field-based age was found for four other standard forest units. The mean difference between FRI- and field-based stand height was significantly different from zero for all tested standard forest units; on average the FRI-based height was 1.37 m lower for four standard forest units and 1.64 m higher for three standard forest units. No significant difference in stand stocking was detected for six of the standard forest units while for the seventh the FRI-based stocking was on average 0.3 lower than respective field estimates. This study provides baseline data that may be used (with additional information if needed) as adjustment factors for FRI-based stand attributes, as a template for other FRI validation studies, and as a basis to recommend that a new inventory be conducted and/or to prioritize re-inventory activities. The methods can also be adopted to document and improve the accuracy of FRI data for all forest management units in Ontario.

- Pitt, D.G., T. Meyer, M. Park, L. MacDonald, T. Buscarini and D.G. Thompson. 2006. **Application of slow-release tablets to enhance white pine regeneration: Growth response and efficacy against white pine blister rust.** Can. J. For. Res. 36(3): 684-698.

Three field studies were established in northeastern Ontario to test the ability of slow-release tablets to provide prophylactic protection against white pine blister rust (caused by *Cronartium ribicola* J.C. Fisch.) and thereby improve the long-term survival, health, and growth of eastern white pine seedlings. Experimental treatments included factorial rate combinations the fungicide triadimefon (Bayleton®), the insecticide imidacloprid (Merit®), and fertilizer (N-P-K, 15:8.5:3.75). Mean foliar fungicide residues increased to maximal levels (0.21 to 3.1 µg/g fresh mass (fm)) within 1 to 2 years post-treatment and declined markedly to <0.3 µg/g fm 3 to 4 years post-treatment. Dose-dependent and temporal trends observed in foliar residue levels were reflected by parallel trends in efficacy. At =2000 ppm triadimefon, infection rates were reduced to between 35% and 70% and mortality rates were reduced to between 6% and 52% over seven growing seasons across the three sites. In contrast, untreated seedlings had infection rates between 60% and 98% and mortality rates between 30% and 90%. Neither fungicide nor insecticide treatments had significant effects on surviving seedling growth. Differences in fungicide uptake, disease incidence, and seedling growth in response to fertilization were observed among the three sites. Direct weed control, provided at one site, appeared to offer relatively greater health and growth benefits than fertilization.

- Pitt, D.G., A. Morneau, W.C. Parker, A. Stinson and L. Lanteigne. 2009. **The effects of herbaceous and woody competition on planted white pine in a clearcut site.** For. Ecol. Manage. 257(4): 1281-1291.

The authors investigated the effects of herbaceous and woody vegetation control on the survival and growth of planted eastern white pine seedlings through six growing seasons. Herbaceous vegetation control involved the suppression of grasses, forbs, ferns, and low-shrubs, and was maintained for 0, 2, or 4 years after white pine seedlings were planted. Woody control involved the removal of all tall-shrub and deciduous trees, and was conducted at the time of planting, at the end of the second or fifth growing seasons, or not at all. Seedling height and basal diameter responded positively and proportionally to duration of herbaceous vegetation control. Gains associated with woody control were generally not significant unless some degree of herbaceous vegetation control was also conducted. Only herbaceous control increased pine crown closure and rate of crown closure. Herbaceous control and the presence of 5000 to 15,000 stems per hectare of young overtopping aspen were associated with reduced weevil injury and increased pine height growth. The results suggest that white pine restoration strategies on clearcut sites should focus on the proactive, early management of understory vegetation and the gradual reduction of overtopping cover from woody vegetation to create a seedling light environment that supports acceptable growth with minimal weevil damage.

- Pitt, D.G., P.G. Comeau, W.C. Parker, D. MacIsaac, S. McPherson, M.K. Hoepting, A. Stinson and M. Mihajlovich. 2010. **Early vegetation control for the regeneration of a single-cohort, intimate mixture of white spruce and trembling aspen on upland boreal sites.** Can. J. For. Res. 40(3): 549-564.

In Canada's boreal forest region, there is increasing demand for practical regeneration strategies that will recreate mixed stands of white spruce and trembling aspen. In 2002, an experiment was implemented in

both west-central Alberta and northeastern Ontario to better understand the effects of herbaceous and woody vegetation control on crop tree survival and growth, within the context of prescription development for the regeneration of a single-cohort, intimate mixture of spruce and aspen. After five growing seasons, good spruce growth, health, and survival were observed with 2 m radial treatments consisting of herbaceous and woody (i.e., complete) vegetation control centred on trees planted at 5 m spacing. These spruce were 4%-64% taller and 68 to 178% larger in stem diameter than untended trees, leading to 167 to 1166% gains in stem volume, and were at least equivalent to the same stock grown at 2.5 m spacing and provided with complete, continuous relief from competition. Removing only the woody vegetation within treated radii stimulated herbaceous competition, resulting in reduced survival and growth of spruce and reduced height of surrounding aspen. Early results suggest that spot treatments that provide two to four years of relief from herbaceous and woody competition may offer a practical strategy for growing spruce with aspen.

Powell, S.R., L.D. Daniels and T.A. Jones. 2009. **Temporal dynamics of large woody debris in small streams of the Alberta foothills, Canada.** Can. J. For. Res. 39(6): 1159-1170.

Large woody debris (LWD) is a key link between riparian forests and streams; however, the temporal dynamics of in-stream wood remains poorly quantified. Using dendrochronology, the authors evaluated the dynamics of five *Pinus*-dominated and five *Picea*-dominated riparian forests in the foothills of Alberta and cross-dated the ring widths of 186 pieces of LWD. Time since death of LWD ranged from 2 to 143 years, with maximums of 86 and 143 years for *Pinus* and *Picea*, respectively. Recruitment of *Pinus* LWD was influenced by stand-replacing fires followed by self-thinning about 40 years after stand establishment. In uneven-aged *Picea*-dominated forests, tree mortality and LWD recruitment were due to fine-scale disturbances. Time since death increased significantly with decay and position classes, which resulted in changes in LWD function through time. LWD persisted in the bridge position for about 30 years. Bridged LWD was least decayed, was significantly longer, and had greater volume than LWD in other positions. LWD remained in partial bridge and loose positions about 15 years and >80 years when submerged in water and buried in sediment. Given the persistence of LWD, the authors concludes that management that alters wood abundance and recruitment has short- and long-term implications for the structure and function of small streams.

Rommel, T.K. and A.H. Perera. 2009. **Mapping natural phenomena: Boreal forest fires with non-discrete boundaries.** Cartographica 44(4): 274-288.

Forest fires are spatially and temporally frequent in the boreal forest biome and continue to alter the spatial mosaic of its forest cover. Some of these fires occur in remote locations where direct socio-economic effects are negligible, and are therefore not suppressed. However, these natural fires have many ecological consequences, and their monitoring and mapping pose both an important and a challenging task. The current state of the art for fire-event mapping in remote northern Ontario is conducted at variable cartographic scales and generally relies on recording the approximate perimeters of the burned area from fixed-wing aircraft or helicopters with a handheld global positioning system receiver. All such techniques treat forest-fire boundaries, regardless of their detection and mapping resolutions or of the irregularity and gradient-like characteristics of their burned/not-burned interface, as crisp lines. Here a procedure is described for standardizing the mapping of forest fires by an approach using high-spatial-resolution IKONOS satellite imagery that considers the actuality of gradual boundaries by assessing the fire-membership strength of each pixel prior to developing a footprint describing an individual fire event. The case study is from northern Ontario, Canada, where the remote boreal forest fires are not regularly suppressed or monitored/mapped using traditional means. Furthermore, the analysis explores the sensitivity of this mapping effort to spatial resolution when describing measures of fire-footprint spatial geometry. Mapping results are compared with fire boundaries obtained by other means, using a series of overlap statistics to assess their spatial coincidence.

Rempel, R.S., J. Baker, P.C. Elkie, M.J. Gluck, J. Jackson, R.S. Kushneriuk, T. Moore and A.H. Perera. 2007. **Forest policy scenario analysis: Evaluating the effectiveness of coarse-filter policy options on conserving forest songbird communities.** Ont. Min. Nat. Resour., Centre for Northern For. Ecosystems Res. Thunder Bay, ON. CNFER Tech. Rep. No. 002. 32 p.

The information presented in this report has been published in two journal articles. Some sections of this report were summarized to focus the information presented to be more relevant and useful for forest

management practitioners and policymakers. For more in depth descriptions of the methods and results refer to the original articles:

- Rempel, R. S., J. Baker, P. C. Elkie, M. J. Gluck, J. Jackson, R. S. Kushneriuk, T. Moore, and A. H. Perera. 2007. Forest policy scenario analysis: Sensitivity of songbird community to changes in forest cover amount and configuration. *Avian Conserv. Ecol.* 2(1): 5. [online] URL: <http://www.ace-eco.org/vol2/iss1/art5/>

- Rempel, R. S. 2007. Selecting focal songbird species for biodiversity conservation assessment: response to forest cover amount and configuration. *Avian Conserv. Ecol.* 2(1): 5. [online] URL: <http://www.ace-eco.org/vol2/iss1/art6/>

Rempel, R.S., J. Baker, P.C. Elkie, M.J. Gluck, J. Jackson, R.S. Kushneriuk, T. Moore and A.H. Perera. 2007.

Forest policy scenario analysis: sensitivity of songbird community to changes in forest cover amount and configuration. *Avian Conserv. Ecol.* 2(1): 5 [online].

Changes in mature forest cover amount, composition, and configuration can be of significant consequence to wildlife populations. The response of wildlife to forest patterns is of concern to forest managers because it lies at the heart of such competing approaches to forest planning as aggregated vs. dispersed harvest block layouts. A species assessment framework was developed to evaluate the outcomes of forest management scenarios on biodiversity conservation objectives. Scenarios were assessed in the context of a broad range of forest structures and patterns that would be expected to occur under natural disturbance and succession processes. Spatial habitat models were used to predict the effects of varying degrees of mature forest cover amount, composition, and configuration on habitat occupancy for a set of 13 focal songbird species. A spatially explicit harvest scheduling program was used to model forest management options and simulate future forest conditions resulting from alternative forest management scenarios, and used a process-based fire-simulation model to simulate future forest conditions resulting from natural wildfire disturbance. Spatial pattern signatures were derived for both habitat occupancy and forest conditions, and these were placed in the context of the simulated range of natural variation. Strategic policy analyses were set in the context of current Ontario forest management policies. This included use of sequential time-restricted harvest blocks (created for woodland caribou conservation) and delayed harvest areas (created for American marten conservation). This approach increased the realism of the analysis, but reduced the generality of interpretations. Forest management options that create linear strips of old forest deviated the most from simulated natural patterns, and had the greatest negative effects on habitat occupancy, whereas policy options that specify deferment and timing of harvest for large blocks helped ensure the stable presence of an intact mature forest matrix over time. The management scenario that focused on maintaining compositional targets best supported biodiversity objectives in providing the composition patterns required by the 13 focal species, but this scenario may be improved by adding some broad-scale spatial objectives to better maintain large blocks of interior forest habitat through time.

Rice, J.A. and R. Man. 2008. **Stand-level adaptive management (SLAM) mixedwood project.** Pp. 57-62 in *Implementing Ecosystem-based Management Approaches in Canada's Forests: A Science-Policy Dialogue.* Nat. Resour. Can., Can. For. Serv., Sci. Progr. Br., Ottawa, ON.

This summary outlines how the Stand-Level Adaptive Management (SLAM) mixedwood project provides a working model for the ecosystem approach to forest management in Ontario.

Routledge, R.G. 2007. **Sampling methodology for studying boreal post-fire residual stand structure with high resolution aerial photography and field plots.** Ont. Min. Nat. Resour., Ont. For. Res. Inst., Sault Ste. Marie, ON. For. Res. Inf. Pap. No. 169. 37 p. + append.

The use of high resolution aerial photography is documented as an alternative to traditional field sampling methods for assessing post-fire residual structure. High resolution photography (HRP), also termed large scale photography (LSP), refers to aerial photographs interpreted at scales of 1:2,500 or larger. Eleven fires were selected for sampling across boreal Ontario in 2005. Within fires, HRP was used to sample residual structure, i.e., trees, snags, and downed wood, in point samples of 0.05 hectare circular plots within one to four months post-fire ignition. Fifty field plots were established in four of the sample fires for error assessment

of photo-interpretation and to allow short-term monitoring of changes in post-fire residual structure. Methods used to select fires, capture and interpret sample photographs, and establish and assess field sample plots are described. Approximate costs of collecting comparable residual structure data were \$130 per plot for HRP vs. \$1,012 per plot for field sampling. When error assessment costs were included in HRP estimates, per plot costs rose to \$217. Half the cost of HRP sampling was for photo capture, including helicopter ferry time. Nearly one third of the field sampling cost was for labour, while another third was operational costs.

Sharma, M., M. Smith, H.E. Burkhart and R.L. Amateis. 2006. **Modeling the impact of thinning on height development of dominant and codominant loblolly pine trees.** *Ann. For. Sci.* 63(4): 349-354.

Data collected from loblolly pine thinning study plots established in plantations on cutover, site-prepared lands were used to evaluate thinning effect on height growth of dominant and codominant loblolly pine trees. Height growth was reduced initially by thinning but was increased three years following thinning. Twelve years after thinning, the average total height of dominant and codominant trees in thinned stands exceeded its counterpart in unthinned stands. Initial growth response to thinning was less at older stand ages than at younger ages. A model was constructed to characterize the development of height in thinned and unthinned stands. This model reflects the initial suppression of dominant and codominant height growth followed by an acceleration resulting from thinning.

Sharma, M., H.E. Burkhart and R.L. Amateis. 2007. **Scaling taper relationships from miniature-scale to operational-scale stands of loblolly pine.** *For. Sci.* 53(5): 611-617.

Taper relationships for trees grown in miniature- and operational-scale stands of loblolly pine were established using stem analysis data from 106 and 173 trees, respectively. Tree taper was modelled using segmented polynomial and dimensionally compatible taper equations. The relationship was then scaled from miniature to operational scale using the profiles obtained from these taper equations. Stump diameter was used in the taper equations instead of breast height diameter in scaling the relationship. A simple linear regression equation described the taper relationship between trees grown at miniature and operational scales. The fit statistics for both the segmented polynomial and dimensionally compatible taper equations were comparable at both scales. In terms of predictive accuracy, however, the segmented polynomial taper equation was superior to the dimensionally compatible taper equation in scaling the taper relationship for trees from miniature- to operational-scale plots.

Sharma, M. and J. Parton. 2007. **Height-diameter equations for boreal tree species in Ontario using a mixed-effects modeling approach.** *For. Ecol. Manage.* 249(3): 187-198.

Height-diameter relationships based on stand characteristics (trees per hectare, basal area, and dominant stand height) were investigated for balsam fir, balsam poplar, black spruce, jack pine, red pine, trembling aspen, white birch, and white spruce using data from permanent growth study plots in northern Ontario, Canada. Approximately half the data were used to estimate model parameters with the rest used for model evaluation. Multiple Chapman-Richards functions with parameters expressed in terms of various stand characteristics were fit to determine the best models for predicting height. Models providing the most accurate prediction of height included basal area, trees per hectare, dominant stand height, and diameter at breast height (DBH). A mixed-effects modelling approach was applied in fitting the models for all tree species. Heights predicted by models including random-effects parameters (calibrated response) were compared with those developed without random-effects parameters (fixed-effects response). Including the random parameter consistently resulted in a better fit to the data (smaller AIC values) and improved prediction accuracy.

Sharma, M. and S.Y. Zhang. 2007. **Stand density management diagram for jack pine stands in eastern Canada.** *North. J. Appl. For.* 24(1): 22-29.

A stand density management diagram was developed for jack pine stands using data obtained from 125 permanent sample plots (PSPs) established in Ontario and 232 PSPs in Quebec, Canada. The resulting diagram was evaluated using data from 40 PSPs established in Ontario. Recently developed and efficient models have been used in constructing the diagram to estimate diameters and heights for the trees for

which no diameters or heights were recorded at the time of stand inventory. Relative density indices of 0.15, 0.40, and 0.55 were used, corresponding to the line of approximate crown closure, the limit of the productive zone, and the lower limit of competition-related mortality, respectively. If two stand characteristics are known, from among mean total tree volume, quadratic mean diameter, trees per hectare, and average dominant height, the diagram can be used to obtain the others. The consequences of various thinning scenarios can be plotted and visualized in the field without the need for computer simulation.

Sharma, M., J. Parton, M. Woods, P. Newton, M. Penner, J. Wang, A. Stinson and F.W. Bell. 2008. **Ontario's forest growth and yield modelling program: Advances resulting from the Forestry Research Partnership.** For. Chron. 84(5): 694-703.

In October 1999, the Canadian Ecology Centre-Forestry Research Partnership (CEC-FRP) was formed and initiated a series of projects that collectively were aimed at characterizing, quantifying, and ultimately increasing the economically available wood supply. Comprehensive, defensible, and reliable forecasts of forest growth and yield were identified as key knowledge gaps. The CEC-FRP, with support from the broader science community and forest industry, initiated several new research activities to address these needs, the results of which are outlined briefly in this paper. The authors describe new stand level models (e.g., benchmark yield curves, FVSOntario, stand density management diagrams) that were developed using data collected from permanent sample plots and permanent growth plots established and remeasured during the past 5 decades. Similarly, they discuss new height-diameter equations developed for eight major commercial tree species that specifically account for stand density. As well, they introduce a CEC-FRP-supported project aimed at developing new taper equations for plantation grown jack pine and black spruce trees established at varying densities. Furthermore, they provide an overview of projects undertaken to explore measures of site productivity. Available growth intercept and site index equations are being evaluated and new equations are being developed for major commercial tree species as needed. The authors illustrate how these efforts are advancing Ontario's growth and yield program and supporting the CEC-FRP in achieving its objective of increasing the supply of fibre by 10% in 10 years while maintaining forest sustainability.

Sharma, M. and J. Parton. 2009. **Modeling stand density effects on taper for jack pine and black spruce plantations using dimensional analysis.** For. Sci. 55(3): 268-282.

A taper equation was developed for jack pine and black spruce trees growing at varying density using a dimensional analysis approach. Data used in this study came from stem analysis on 1,135 jack pine and 1,189 black spruce trees sampled from 25 even-aged monospecific plantations in the Canadian boreal forest region of Northern Ontario. About half of the trees were randomly selected for model development with the remainder used for model evaluation. A nonlinear mixed-effects approach was applied in fitting the taper equation. The predictive accuracy of the model was improved by including random-effects parameters for a new tree based on upper stem diameter measurements. Three scenarios of using upper stem diameter measurements to predict random effects were examined for predictive accuracy: one diameter at any height along the bole; two diameters, one each from below and above breast height; and three diameters, one from below and the other two from above breast height. For practical reasons, the upper height at which the diameter was measured was limited to 65% of total tree height. For the first scenario, the model calibrated using a diameter measurement from between 34 and 38% of total height provided the best predictions of inside-bark diameters. For the second scenario, the model calibrated using one diameter from near the stump and the other from close to 65% of total height produced the least bias in predicting inside-bark diameters. For the third scenario, the model calibrated using the diameters from near the stump and at approximately 35 and 65% of total height provided the highest prediction accuracy.

Sharma, M., F.W. Bell, R.G. White, A. Morneau and W.D. Towill. 2010. **Seedling size and woody competition most important predictors of growth following free-to-grow assessments in four boreal forest plantations.** For. Chron. 86(2): 213-224.

The authors examined the effects of various classes of competitors on crop tree growth in the context of free-to-grow standards using regression analysis. They found that seedling size accounted for most of the variation in height and volume growth of jack pine and black spruce plantations. Including herbaceous and woody competition as explanatory variables accounted for the additional variation in crop tree growth. In the

plantation initiation phase (years 2 to 6), the presence of herbaceous competitors generally reduced conifer growth but in the first part of the stem-exclusion phase (years 7 to 12) increased their growth. In all four boreal plantations in this study, woody competitors reduced conifer growth in both the initiation and stem-exclusion phases. These results have relevance to forest managers who develop and/or use free-to-grow surveys.

- Smith, G.K.M. and L.J. Buse, comp. 2008. **Evolving challenges and changing expectations for forestry extension and technology transfer: Meeting the needs of people and forests around the globe.** Ont. Min. Nat. Resour., Ont. For. Res. Inst. Sault Ste. Marie, ON. For. Res. Inf. Pap. No. 172. 74 p.

Early in the 21st century, the inter-dependency between humans and forests has never been greater. Ecosystems are strained by multiple natural and human-caused disturbances. Demand for raw materials is on the rise. Forests are supporting a range of non-timber needs such as conservation of soil and water resources. Thousands of small communities dependent on forests are facing new challenges wrought by globalization. In this volume, contributors from five continents provide their perspectives on the role for extension and technology transfer in meeting the needs of people and forests around the globe. Several contributions address best practices for sustainable management on areas under public or private forest land ownership. Others focus on socio-economic conditions and measures for encouraging stewardship at the community level. Optimizing the uptake of knowledge is another theme evident in the collection, with a number of papers sharing approaches for improving policy, planning, and practice. Examples of effective programs and partnerships are provided to share experiences in supporting the need to adapt to changing ecosystems and changing human needs. This compilation provides documentation to support the 9th Extension Working Party Symposium of the International Union of Forest Research Organizations (IUFRO), hosted in Mattawa and Ottawa, Ontario, Canada, in September 2008.

- Smith, G.K.M., J.F. Pineau and F.W. Bell. 2008. **Knowledge transfer and extension in the Canadian Ecology Centre - Forestry Research Partnership: From awareness to uptake.** For. Chron. 84(5): 748-755.

Knowledge transfer, including awareness, transfer, extension, training, and education activities, was purposely incorporated into the Canadian Ecology Centre - Forestry Research Partnership (CEC-FRP) at an early stage as part of an adaptive management approach. Over the course of seven years, the level of involvement from researchers, policymakers, and forest resource managers in knowledge transfer activities progressed from passive to interactive participation, with each successive stage requiring greater attention to timing and the capacity of participants to take in new knowledge. An interactive approach, dubbed core teams, proved essential in overcoming barriers to the flow of knowledge into practice. Four examples: (1) revising growth and yield predictions, (2) integrating spatial and non-spatial landscape analysis tools, (3) developing and applying advanced silvicultural decisionmaking, and (4) applying spray delivery systems, are used to convey the success of knowledge transfer and extension efforts in the CEC-FRP and the essential role of the core teams. Physical, human, and financial resources, coupled with strong involvement by partner organizations, were key factors in the success of knowledge transfer efforts.

- Smith, T., B. Dalziel and R.G. Routledge. 2008. **A proposed method to rank the intensity of boreal forest fires in Ontario using post-fire high resolution aerial photographs.** Ont. Min. Nat. Resour., Ont. For. Res. Inst. Sault Ste. Marie, ON. For. Res. Inf. Pap. No. 170. 23 p.

Fire intensity is a crucial descriptor of fire behaviour that may also be an important determinant of many types of ecological dynamics. However, fire intensity has proven challenging to measure directly. Indirect estimates of fire intensity are often confounded with the ecological effects of the fire, precluding further study of the relationships between intensity and population or community dynamics. The authors describe a novel method for estimating the intensity of fires in the boreal forest of Ontario using high resolution imagery taken soon after fire. This method relies on an empirical relationship between the branch structure of fire-killed trees (crown fraction burned) and fire intensity rankings provided by the Canadian Forest Fire Behaviour Prediction System (FBP) and its field guide for fire managers. They describe the results of the application of this method to 660 high resolution aerial photography sample plots, each 25 m in diameter, dispersed among 11 fires that occurred in the boreal forest of Ontario in 2005. They were able to rank fire intensities into five groups, that are equivalent to <10, 10-500, 500-2000, 2000-4000, and >4000 Kw·m⁻¹ in the FBP. The proposed method

could be a useful proxy for the expensive instrumentation required for direct fire intensity measurements, and may represent a useful tool for forest and fire managers and research on fire-forest interaction at a variety of scales.

- Smokorowski, K.E., T.C. Pratt, W.G. Cole, L.J. McEachern and E.C. Mallory. 2006. **Effects on periphyton and macroinvertebrates from removal of submerged wood in three Ontario lakes.** *Can. J. Aquat. Fish. Sci.* 63(9): 2038-2049.

Forty to 70% of nearshore wood habitat was removed from three lakes to test the link between habitat and productive capacity, specifically focusing on the provision of substrate for periphyton and invertebrate production by submerged wood. The objectives were fourfold: (i) to calculate the total amount of invertebrate and periphyton biomass removed with the wood; (ii) to explore wood's value as habitat for invertebrates and periphyton; (iii) to determine the response within residual epixylic periphyton and invertebrate biomass; and (iv) to assess interactions between periphyton and invertebrates and other factors that may influence wood's productivity. Invertebrate biomass was greater on wood than in sediment, but the total available sediment area exceeded that of wood, thus a relatively small proportion of overall productivity was lost. Highly decayed wood supported greater chlorophyll *a* concentrations and more invertebrate biomass and diversity than fresh wood. The removal had no measurable effect on whole-lake water chemistry, nor did it result in a response in residual epixylic periphyton and invertebrate biomass. The authors concluded that they permanently reduced a dynamic and concentrated biomass of primary and secondary productivity in lakes by removing submerged wood habitat.

- Sobze, J.-M., M.T. Ter-Mikaelian and S.J. Colombo. 2006. **Wood supply in Ontario: The road to better prediction.** *Ont. Min. Nat. Resour., Ont. For. Res. Inst. Sault Ste. Marie, ON. For. Res. Inf. Pap. No. 165.* 11 p. + append.

A secure and predictable wood supply is critical to the health of Ontario's forest industry. Wood supply is predicted using a number of data sources and models. Forecasting wood supply requires that long-term silvicultural activities be defined and forest growth, succession, natural disturbance, and harvest rates be predicted for periods of 100 or more years. In this report, the authors identify and prioritize issues affecting wood supply prediction and recommend actions to improve the process of estimating wood supply. To assemble the prioritized list, they sought expert opinion from forestry specialists in Ontario through an electronic survey and a workshop. Overall, 42% of issues identified as contributing to uncertainty in wood supply estimation were related to forest resource inventory and growth and yield. The top 5 areas considered most in need of improvement are: (1) Improved linkages between forest resource inventory and growth and yield data (for example, development of a method to calibrate/validate one with another, and improved methods of assigning growth and yield curves to stands in forest resources inventory); (2) More realistic information to predict and validate successional changes at various stages of stand development; (3) Additional growth and yield curves for planted and naturally regenerated stands; (4) Update forest resource inventory more frequently; (5) Better data on factors affecting site productivity (e.g., soil moisture and nutrient regimes) and inclusion of these factors in growth and yield models. To develop a plan for addressing issues of uncertainty in wood supply prediction, they proposed the following: First, each issue needs to be clearly described. Second, a list of ongoing/recent projects relevant to Ontario's needs for addressing wood supply prediction needs to be developed. Third, the list needs to be assessed to determine the speed with which the needs can be addressed, the cost to address them, and the degree to which wood supply estimates would be improved. This would result in a prioritized list from which an action plan could be prepared.

- Subedi, N., M. Sharma and J. Parton. 2009. **An evaluation of site index models for young black spruce and jack pine plantations in a changing climate.** *Ont. Min. Nat. Resour., Appl. Res. Devel. Br., Sault Ste. Marie, ON. Climate Change Res. Rep. CCRR-15.* 16 p.

The authors evaluated the most popular published site index (SI) models to determine their suitability to assess climate change effects on the growth of young jack pine and black spruce. Nineteen SI equations, including those commonly applied in Ontario, were evaluated using data from 142 black spruce and 132 jack pine trees collected from 50 plantations (25 per species) from across boreal Ontario. The equations included were base age specific (BAS), base age invariant (BAI), and dynamic. These models were evaluated based

on fit statistics and predictive abilities measured by mean bias (observed-predicted), mean absolute bias (MAB), and root mean square error (RMSE). For BAS SI models, the simplified version of existing natural black spruce and jack pine site index models (the second and third variants of Chapman Richard model for both species and the third and second variants of log logistic models for black spruce and jack pine trees, respectively) were superior to others for predicting heights of dominant or co-dominant trees. For BAI SI models, of the seven models compared three demonstrated superior predictive abilities in terms of bias across site, site quality, and age classes for both species. Of the dynamic models, the four polymorphic models generated similar predictive accuracy across site, site quality, and age classes for both species. However, only two of them resulted in more consistent estimates for more productive sites. Biases in height predictions were relatively large, which reduced the utility of the anamorphic SI model. Even though the goodness of fit was acceptable for most of the models assessed, the predictive accuracy of the dynamic models was not as high as expected. This indicates that the local parameter (site specific parameter) used in dynamic models is not adequately robust to explain the variability among sites. Therefore, including edaphic and climatic variables directly in the models could improve model efficacy by helping to explain site specific variability.

Subedi, N. and M. Sharma. 2010. **Evaluating height-age determination methods for jack pine and black spruce plantations using stem analysis data.** North. J. Appl. For. 27(2): 50-55.

Six height age determination methods (Graves, Lenhart, Carmean, Newberry, ratio, and ISSA) were evaluated for their accuracy and sensitivity to sample size in determining height-age pairs using stem analysis data from plantation-grown black spruce and jack pine trees from Ontario, Canada. Twenty-three disks (sections) were used from 102 jack pine and 93 black spruce trees each for evaluation. The Graves, ratio, and Newberry methods were unbiased for determining height-age pairs for both black spruce and jack pine across the site productivity gradient and different crown classes. However, on the basis of the magnitude of height prediction bias, reconstructed tree profiles, and the amount of information required for height-age determination, the Graves method with at least 13 stem sections is recommended for height-age determination.

Ter-Mikaelian, M.T., S.J. Colombo and J. Chen 2006. **A critical analysis of down woody debris in Ontario forests.** In *Our Woods: Wild and Working*. Proc 2006 SAF Nat. Conv. Pittsburgh, PA, Soc. Am. For. CD-ROM: 10 p.

Results of a study estimating volume of down woody debris (DWD) in forests of Ontario, Canada are presented. The study objectives were to estimate DWD for various forest types and conditions, and to develop a method for predicting the amount of DWD from site and stand characteristics. Analysis was based on DWD data from 491 permanent sample plots in boreal and mixedwood forests of Ontario. Amount of DWD volume and mass ranged from 0.1 to 68.6 t·ha⁻¹ and from 0.5 to 239 m³·ha⁻¹, respectively. Our analysis did not reveal a functional relationship between DWD and stand attributes such as age, height, basal area, stocking, site class, and total tree biomass. Furthermore, the results do not support the U-shaped relationship between DWD accumulation and stand age often reported in the literature. Potential causes of the lack of relationship between DWD and stand attributes, and implications for predicting DWD are discussed.

Ter-Mikaelian, M.T., S.J. Colombo and J.X. Chen. 2008. **Amount of downed woody debris and its prediction using stand characteristics in boreal and mixedwood forests of Ontario, Canada.** Can. J. For. Res. 38(8): 2189-2197.

The authors analyzed data on downed woody debris (DWD) from 435 permanent sample plots in boreal and mixedwood forests of Ontario seeking empirical relationships to predict DWD quantity from stand attributes. In each permanent sample plot, data were collected along three transects, including diameter, tree species, and degree of decomposition of DWD pieces with diameter greater than or equal to 7.5 cm at the point of intersection with the transect. Amounts of DWD in sample plots ranged from 0.7 to 402.7 m³·ha⁻¹ and from 0.1 to 103.4 t·ha⁻¹. Mean DWD values were 65.4 m³·ha⁻¹ and 15.9 t·ha⁻¹ in softwood- and 61.9 m³·ha⁻¹ and 16.5 t·ha⁻¹ in hardwood-dominated plots. The analysis revealed no relationship between DWD and stand age, site index, or stocking for plots dominated by black spruce, eastern white pine, sugar maple, and red oak and weak relationships for plots dominated by jack pine, red pine, trembling aspen, and white birch. The authors

submit that DWD in Ontario's forests should be treated as a constant factor until the relationship between the amount of DWD and present stand condition is better understood and discuss considerations for future studies on DWD.

Ter-Mikaelian, M.T., S.J. Colombo and J.X. Chen. 2008. **Fact and fantasy about forest carbon.** *For. Chron.* 84(2): 166-171.

The Boreal Campaign initiated by environmental non-governmental organizations has resulted in a number of public statements about detrimental effects of harvesting on boreal forest carbon stocks. These statements are examined in the context of Ontario's boreal forest. A review of scientific literature and the results of the authors' original work on forest carbon demonstrate that these statements are based on either incomplete or inaccurate use of published scientific information. The authors conclude that forest management in Ontario, as governed by the Crown Forest Sustainability Act, increases total boreal forest carbon stock over the long term and that these conclusions are likely applicable to other jurisdictions where boreal forests are managed sustainably.

Ter-Mikaelian, M.T., S.J. Colombo and J.X. Chen. 2009. **Estimating natural forest fire return interval in northeastern Ontario, Canada.** *For. Ecol. Manage.* 258(9): 2037-2045.

Long-term forest fire regime was simulated for the Moose River Forest Management Unit (FMU) in northeastern Ontario. The simulated area has not been managed for timber production and fire suppression activity has been minimal. The available data included fire records for 1970 to 2006 and forest age structure from forest resource inventory completed in 1978. The fire regime was simulated using a simple percolation model driven by three parameters: probabilities of fire spread during low and high fire activity years and of a given year being a low fire activity year. The model successfully generated a long-term fire regime producing age structure and 37-year-long fire records similar to those observed for the Moose River FMU. The simulation results suggest that fire return interval in northeastern Ontario is likely much shorter than indicated by estimates based exclusively on data from the last four decades of fire activity, and it is possible that the fire regime in northeastern Ontario has not changed since mid-1800s but rather is characterized by relatively long periods of low incidence of fire interspersed with pulses of high fire activity.

Thomas, V., D.A. Finch, J.H. McCaughey, T. Noland, L. Rich and P. Treitz. 2006. **Spatial modelling of the fraction of photosynthetically active radiation absorbed by a boreal mixedwood forest using a lidar-hyperspectral approach.** *Agric. For. Meteorol.* 140(1-4): 287-307.

The spatial variability of the fraction of photosynthetically active radiation absorbed by the canopy (fPAR) was characterized for a heterogeneous boreal mixedwood forest site located in northern Ontario, Canada, based on relationships found between PAR and light detection and ranging (lidar) data over different canopy architectures. Estimates of fPAR were derived from radiation measurements made above the canopy at a flux tower and below-canopy radiation was measured across a range of species compositions and canopy architectures. Airborne lidar data were used to characterize spatial variability of canopy structure around the flux tower and a map of mean canopy chlorophyll concentration was derived from airborne hyperspectral imagery. The strongest correlations between mean lidar height and fPAR occurred when using points that fell within a theoretical cone which originated at the PAR sensor having a solid angle $\alpha = 55$ degrees. For diffuse conditions, the correlation between mean lidar height versus fPAR x chlorophyll was stronger than between mean lidar height versus fPAR by 8% for mean daily fPAR and from 10 to 20% for diurnal fPAR, depending on solar zenith angle. For direct light conditions, the relationship was improved by 12% for mean daily fPAR and 12 to 41% for diurnal relationships. Linear regression models of mean daily fPAR x chlorophyll versus mean lidar height were used with gridded lidar data and the canopy chlorophyll map to generate maps of mean daily fPAR for direct and diffuse sunlight conditions. Site average fPAR calculated from these maps was 0.79 for direct light conditions and 0.78 for diffuse conditions. When compared to point estimates of mean daily fPAR calculated on the tower, the average fPAR was significantly lower than the point estimate. Subtracting the direct sunlight from the diffuse sunlight fPAR map revealed a distinct spatial pattern showing that areas with open canopies and relatively low chlorophyll (e.g., black spruce patches) had a higher fPAR under direct sunlight conditions, while closed canopies with higher chlorophyll (e.g., deciduous

species) absorbed more PAR under diffuse conditions. These findings have implications for scaling from point measurements at flux towers to larger resolution satellite imagery and addressing local scale heterogeneity in flux tower footprints.

Thomas, V., P. Treitz, J.H. McCaughey, D. Finch, T. Noland, L. Rich and I. Morrison. 2006. **Integration of lidar and hyperspectral data with micrometeorological measurements to develop spatially explicit models of canopy chlorophyll, fPAR, and photosynthesis.** Pp. 145-151 in *Proc. of Silvilaser 2006*. Matsuyama, Japan. Shikoku Res. Cent. and Ehime Univ. Matsuyama, Japan.

The architecture and the physiological status of the forest canopy strongly influences the spatial and temporal variability of the fraction of photosynthetically active radiation absorbed by the canopy (fPAR) and depends upon tree species, size and location of canopy gaps. High resolution hyperspectral and light detection and ranging (lidar) sensors can provide considerable information about the spatial variability of canopy physiological status and structure. This paper reports on an experiment designed to capture the spatial and temporal variability of canopy chlorophyll and fPAR for a complex boreal mixedwood environment in northern Ontario, Canada. Monthly maps of canopy chlorophyll and fPAR under direct and diffuse sunlight conditions are derived from airborne lidar and hyperspectral data. The maps were used in conjunction with micrometeorological measurements of global solar radiation and air temperature recorded at half hourly time steps to model the spatial and temporal variability of photosynthesis for a 1 km radius surrounding a micrometeorological flux tower during summer 2004. Model results were compared to measurements of gross ecosystem photosynthesis (GEP) made using eddy covariance systems attached to the flux tower as part of Fluxnet-Canada's measurement network.

Thomas, V., P. Treitz, J.H. McCaughey, D. Finch, T. Noland, L. Rich and I. Morrison. 2006. **Estimating forest canopy chlorophyll concentration using complementary remote sensing technologies: lidar and hyperspectral data.** Pp. 224-230 in *Proc. of Silvilaser 2006*. Matsuyama, Japan. Shikoku Res. Cent. and Ehime Univ. Matsuyama, Japan.

The potential to use lidar and hyperspectral data to predict canopy chlorophyll (Chl) concentrations was investigated for a spatially complex boreal mixedwood. First, canopy scale application of hyperspectral reflectance and derivative indices were used to estimate Chl concentration. Second, lidar data analyses were conducted to identify structural metrics related to Chl concentration. Third, lidar metrics and hyperspectral indices were combined to determine if Chl estimates could be improved. Of the hyperspectral indices considered, only the derivative chlorophyll index (DCI) and the red-edge inflection point were shown to be good predictors of Chl concentration when mixed-species plots were included in the analysis. Integrating mean lidar first return heights for the 25th percentile with the hyperspectral DCI index further strengthened the relationship to canopy Chl concentration. Maps of total chlorophyll concentration reveal distinct spatial patterns that are indicative of the spatial distribution of species at the site.

Thomas, V., P. Treitz, J.H. McCaughey, T. Noland and L. Rich. 2008. **Canopy chlorophyll concentration estimation using hyperspectral and lidar data for a boreal mixedwood forest in northern Ontario, Canada.** *Int. J. Remote Sens.* 29(4): 1029-1052.

This paper reports results of an investigation of the potential of lidar and hyperspectral data for predicting canopy chlorophyll (Chl) and carotenoid concentrations for a spatially complex boreal mixedwood. First, canopy scale application of hyperspectral reflectance and derivative indices were used to estimate Chl concentration. Second, lidar data analyses were conducted to identify structural metrics related to Chl concentration. Third, lidar metrics and hyperspectral indices were combined to determine if Chl concentration estimates could be improved. Of the hyperspectral indices considered, only the derivative chlorophyll index (DCI) and the red-edge inflection point (p) were good predictors of Chl concentration when mixed-species plots were included in the analysis. Integrating mean lidar first return heights for the 25th percentile with the hyperspectral DCI index further strengthens the relationship to canopy Chl concentration. Maps of total chlorophyll concentration for the study site reveal distinct spatial patterns that are indicative of the spatial distribution of species at the site.

- Thomas, V., J.H. McCaughey, P. Treitz, D.A. Finch, T. Noland and L. Rich. 2009. **Spatial modelling of photosynthesis for a boreal mixedwood forest by integrating micrometeorological, lidar and hyperspectral remote sensing data.** *Agric. For. Meteorol.* 149(3-4): 639-654.

The adaptation of a national/continental-scale model of carbon uptake to the local-scale using highly detailed airborne discrete lidar and hyperspectral data was investigated at a boreal forest mixedwood site in northern Ontario. Spatially explicit maps of canopy chlorophyll concentration and the fraction of photosynthetically active radiation absorbed by the canopy (fPAR) under direct and diffuse radiative conditions were developed for five time periods in 2004 (i.e., winter: January 1-May 31, leaf-out: June 1-20, summer: June 21-July 31 and August 1-31, and senescence: September 1-30). The maps were used in conjunction with meteorological measurements, such as incident total and diffuse PAR, global solar radiation, and air temperature, taken on a flux tower located at the centre of the study. Distinct spatial patterns in fPAR, a result of changes in canopy chlorophyll concentration, are increasingly evident throughout the season because of the variation in species groupings within the 1-km radius surrounding the flux tower. In general, the model shows a good correlation to flux-tower-measured gross ecosystem productivity (GEP) ($r^2 = 0.70$ for 10-day averages throughout the year), with the largest deviations occurring June-July. Species-level data show the influence of a large homogenous patch of black spruce on the tower-measured GEP and demonstrates the contribution of white birch, by far the most dominant species, to the total GEP for the area.

- Thompson, I.D., J.A. Baker, C. Jastrebski, J. Dacosta, J. Fryxell and D. Corbett. 2008. **Effects of post-harvest silviculture on use of boreal forest stands by amphibians and marten in Ontario.** *For. Chron.* 84(5): 741-747.

Much of the southern boreal forest is composed of second-growth stands that have been subjected to a variety of silvicultural treatments ranging from cut and leave to scarification, planting, and tending with herbicides. Understanding of the effects that these treatments may have on wildlife species, as a result of changes to forest structures and species composition, is limited. Forest amphibians, generally, and the American marten are species for which there has been long-standing concern about the effects of forest management. The authors examined the long-term effects at stand and landscape scales of a range of silviculture intensities on these species by comparing the relative abundances of some amphibians and habitat use by marten in forests that were about 32 to 50 years old. American toads appeared to be unaffected by long-term changes in habitat structure and composition resulting from silvicultural techniques. Lower relative abundance of wood frogs was observed in treated stands 20 to 30 years old than in all other stands including uncut old forests. However, abundance in treated stands more than 32 years old did not differ from untreated or uncut stands. This effect may have resulted from lower moisture levels in treated young stands. Marten seemed to respond positively to post-harvest planting and tending treatments, suggesting that basic silviculture provided habitat attributes, notably a higher conifer content, which was favourable to marten.

- Webster, K.L., I.F. Creed, F.D. Beall and R.A. Bourbonniere. 2008. **Sensitivity of catchment-aggregated estimates of soil carbon dioxide efflux to topography under different climatic conditions.** *J. Geophys. Res.-Biogeosci.* 113(G3).

Soil respiration (R_s) is an important component of regional carbon budgets in forested landscapes. Within a sugar maple forest on the Algoma Highlands of the Canadian Shield, mosaics of topographic features create gradients in environmental conditions and carbon pools that influence the pattern of R_s within the region. The sensitivity of catchment-aggregated R_s (CAR) to different spatial partitioning schemes of the landscape under different climate scenarios was examined in two contrasting catchments: one dominated by uplands (C35); the other containing uplands, critical transition zones (transiently saturated areas in isolated depressions or adjacent to wetlands, streams, and lakes), and wetlands. CAR was estimated using a six topographic feature representation of the catchments that included crest, backslope, footslope, toeslope, and inner and outer wetland. CAR was underestimated (-7.4%) or overestimated (30.8%) if coarser spatial partitions were used, but the amount of error differed between catchments and with climatic conditions. A single feature (upland) partitioning scheme performed poorly under all climatic conditions (warm-wet, warm-dry, cool-wet and cool-dry). A two feature (upland and wetland) partitioning scheme showed improvement, but a partitioning scheme with a minimum of three features (upland, transition, and wetland) was needed for

accurate estimates of CAR in topographically varying catchments. The critical transition zone had the highest rates of Rs under all climate scenarios, and the critical transition zone and wetland became increasingly larger contributors to CAR under warmer and drier conditions. These observations point to the importance of accounting for the differential contribution of topographic features to Rs in carbon budget models. Failure to do so may lead to inaccurate estimates of landscape-scale Rs.

Webster, K.L., I.F. Creed, R.A. Bourbonniere and F.D. Beall. 2008. **Controls on the heterogeneity of soil respiration in a tolerant hardwood forest.** *J. Geophys. Res.* 113(G3).

The spatial and temporal distribution of soil respiration (Rs) in forested landscapes and its control by environmental conditions and carbon pools has not been sufficiently investigated. A Rs monitoring strategy targeting different topographic features within a sugar maple forest on the Algoma Highlands on the Canadian Shield revealed that the critical transition zones (transiently wet areas adjacent to wetlands, streams, and lakes) yielded significantly larger Rs than adjacent upland or wetland portions of the catchment. Environmental conditions (soil temperature and soil moisture) explained the majority of variance in Rs. An exponential relationship in which the exponent is a polynomial expression that is linear with respect to temperature and quadratic with respect to moisture explained 57.0% of the variance in Rs. However, inclusion of the quantity of carbon and substrate quality (carbon: nitrogen ratio) in the freshly fallen leaves, and the organic and/or mineral soils into the polynomial regression model explained an additional 15.3% of the variance in Rs. This study highlighted the critical transition zone as major sites of Rs because of the synchronicity in optimal temperature and moisture conditions during the growing season and the large pool of high quality substrate that accumulates in topographic depositional areas.

Webster, K.L., I.F. Creed, M.D. Skowronski and Y.H. Kaheil. 2009. **Comparison of the performance of statistical models that predict soil respiration from forests.** *Soil Sci. Soc. Am. J.* 73(4): 1157-1167.

Soil respiration (Rs) is an important source of carbon dioxide to the atmosphere, yet understanding the processes controlling the combined autotrophic and heterotrophic components has proven challenging. Several statistical models have been developed to explain Rs as a function of physical and chemical conditions, but little effort made to systematically evaluate and compare the performance of these different models. Soils in a sugar maple forest were monitored for Rs and its physical and chemical drivers, and the monitored data were used to fit the most common of these statistical models. Each model was fit using a repeated trials approach and the performance of the model was evaluated with a range of goodness-of-fit measures (RMSE, mean absolute error, correlation coefficient, index of agreement, bias, and Akaike information criterion). An exponential model in which the exponent is a polynomial expression that is linear with respect to temperature and quadratic with respect to soil moisture explained 57% of the variance in Rs and performed well among the goodness-of-fit measures. Inclusion of carbon (C) quantity and substrate quality (as measured by the C/N ratio) in the soils, however, increased the explanation of variance in Rs to 71%. This study showed that combining soil temperature and moisture drivers with soil C quantity and substrate quality significantly improved statistical models predicting soil respiration. Findings support comparing the performance of different statistical models using a repeated trials approach coupled with a range of goodness-of-fit measures to identify controls on Rs within an ecosystem and to assess the generality of these controls on Rs across ecosystems.

Webster, K.L. and J.W. McLaughlin. 2010. **The importance of the water table in controlling dissolved carbon along a fen nutrient gradient.** *Soil Sci. Soc. Am. J.* 74(6): 2254-2266.

Boreal fens are minerotrophic peatlands that act as important control points for dissolved carbon © between upland and aquatic ecosystems. Fens occupy a minerotrophic continuum from "rich," with high water tables and large nutrient contributions from upland sources, to "poor," with low water tables and small nutrient contributions. Dissolved C within these fens will be influenced by the degree of minerotrophy, which in turn affects peat pore water acidity and alkalinity and downstream productivity. To examine how dissolved C concentrations change along the minerotrophic gradient and to explore possible mechanisms controlling their concentration, pore water chemistry was analyzed from piezometers at 25-, 50-, and 100-cm depths in rich, intermediate, and poor fens during the snow-free periods of 2005, 2006 (dissolved organic C [DOC] only), 2007, and 2008. The authors found that dissolved inorganic C (DIC) concentrations increased with

higher water tables (poor < intermediate < rich) and wetter years (2005 < 2007 < 2008). In contrast, DOC concentrations decreased with higher water tables (rich < intermediate < poor), but the effect differed among years. Wetter conditions resulted in high DOC concentrations in the intermediate fen, low concentration in the poor fen, and no change in the rich fen. Correlation analyses suggest that DIC concentrations may be linked to groundwater contribution of carbonate materials and DOC to ionic strength and mechanisms of productivity and decomposition. Although further experimentation is required to verify these mechanisms, the evidence points to the importance of minerotrophic status when considering the role of peatlands in watershed C balances and their response to changing climate.

Williamson, T.B., S.J. Colombo, P.N. Duinker, P.A. Gray, R.J. Hennessey, D. Houle, M.H. Johnston, A.E. Ogden and D.L. Spittlehouse. 2009. **Climate change and Canada's forests: From impacts to adaptation**. Nat. Resour. Can., Can. For. Serv., North. For. Res. Centre, Edmonton, AB; Sustain. For. Manage. Network, Univ. Alberta, Edmonton, AB. 112 p.

Climate change is already affecting Canada's forests. Current visible effects include changes in the frequency and severity of disturbances (such as fires, drought, severe storms, and damaging insect and disease attacks); other less visible changes such as change in the timing of spring bud burst are also underway. One of the consequences of future climate change will be further increases in the frequency and severity of extreme weather events and disturbances. Changes in productivity, species composition, and age-class distribution are also expected. The magnitudes of change in climate that will be faced by Canada's forests and forest management sector and the consequent scale of expected impacts have no historical analogue. Canada's forest sector will need to adapt and it will need to do so without the benefit of prior experience. Forest managers can expect the unexpected and they can expect that change will be ongoing and unrelenting. Some general recommendations for beginning to address climate change in Canada's forest sector include enhancing the capacity to undertake integrated assessment of vulnerabilities to climate change at various scales; increasing resources to monitor the impacts of climate change; increasing resources for impacts and adaptation science; reviewing forest policies, forest planning, forest management approaches, and institutions to assess our ability to achieve social objectives under climate change; embedding principles of risk management and adaptive management into forest management; and maintaining or improving the capacity for communicating, networking, and information sharing with the Canadian public and within the forest sector.

Zakrzewski, W.T. and D.W. MacFarlane. 2006. **Regional stem profile model for cross-border comparisons of harvested red pine (*Pinus resinosa* Ait.) in Ontario and Michigan**. For. Sci. 52(4): 468-475.

In recent years, considerable attention has been paid to the problem of increasing the comparability of wood valuation (e.g., stumpage prices) across different markets, highlighted in the ongoing softwood lumber dispute between the United States and Canada. One major thrust is towards standardizing measurement systems across markets such that volume estimation is more consistent and versatile. As part of the Great Lakes Stem Profile Modelling Project, established to improve the local timber production process and enable cross-border comparisons of timber volumes, the authors present results of a fitting taper (stem profile) model for red pine, an important commercial species in Michigan and Ontario. They developed a joint stem profile model that predicts individual tree volume for red pine with a low standard deviation (SD) of error, demonstrating the feasibility of providing regionally valid stem profile models for major commercial tree species.

Zakrzewski, W.T. and D.W. MacFarlane. 2006. **The role of stem profile models in cross-border comparisons of timber products volume and value**. Pp. 271-278 in U.S.-Canada Forest Products Trade: A bilateral Technical Symposium. East Lansing, MI. Mich. Agric. Exp. Stn.

Difficulties in comparing wood volumes and values between the United States and Canada are outlined, as well as the role of stem profile models in providing a robust and systematic way to link the raw commodity (roundwood) to wood products scaled under dynamic merchantability standards. The authors propose a system to produce statistically and legally defensible estimates of the volume of timber products to improve communication between trade partners, using Great Lakes tree species as an example.

- Zakrzewski, W.T. and F. Schnekenburger. 2006. **Stem Data Management System for the Great Lakes Stem Profile Modelling Project, Version 2.0.** Ont. Min. Nat. Resour., Ont. For. Res. Inst. Sault Ste. Marie, ON. For. Res. Note. No. 67. 16 p.

In this note, the current status of and background documentation is provided for the Stem Data Management System (SDMS) developed in support of the Great Lakes Stem Profile Modelling Project (GLSPMP). The GLSPMP was established to define Zakrzewski's (1999) stem profile model for major commercial tree species in the Great Lakes Region, for which a relevant regional database containing stem profile measurements was needed. The ultimate objective the project was to improve local timber product estimates and to enable cross border comparisons of harvest and productivity potential of forest sites within the region of interest. SDMS V. 2.0, which is designed to facilitate the collation, management, and analysis of stem analysis data, contains measurements from almost 23,000 trees. The system allows data from a variety of sources and formats to be integrated into a single, unified database that can be easily used, primarily for stem profile modelling.

- Zakrzewski, W.T., M. Penner and D.W. MacFarlane. 2007. **Defining stem profile model for wood valuation of red pine in Ontario and Michigan with consideration of stand density influence on tree taper.** Pp. 281-290 in *Proceedings of the Seventh Annual Forest Inventory and Analysis Symposium*. Portland, ME. USDA For. Serv., Washington, DC.

As part of the Canada-United States Great Lakes Stem Profile Modelling Project, established to support the local timber production process and to enable cross-border comparisons of timber volumes, the authors present results of fitting Zakrzewski's (1999) stem profile model for red pine growing in Michigan, United States, and Ontario, Canada. The model was fitted as a system of simultaneous equations using a three-stage least squares regression method. The influence of stand density on red pine tree taper was explored using data from a spacing trial in Ontario.

- Zakrzewski, W.T. 2009. **Defining tree taper: A challenge for growth and yield modelling in Ontario.** For. Chron. 85(6): 897-899.

In this note, the author argues statements made in a recently published growth and yield paper and proposes a set of standard criteria for evaluating taper models.

- Zakrzewski, V., F. Schnekenburger and P. Kozlowski. 2010. **Tools for optimizing timber product mix: User's guide for Visualizer - Buck.** Ont. Min. Nat. Resour., Ont. For. Res. Inst., Sault Ste. Marie, ON. For. Res. Info. Pap. No. 174. 18 p. + append.

Resource managers require information about the amount and types of timber that can be produced from forest stands. Here the authors present information about two software programs, Visualizer V. 2.0 and BUCK V. 2.0, which facilitate the management of stem profile data, fitting taper models, and producing optimized, locally valid and therefore legally defensible, individual-tree-based timber product mix yield tables. The suggested solutions are applicable for any tree species of single stem form. Briefly, round-wood timber products are defined by the user who determines desired size limits (length, minimum diameter) and rankings of log categories (sawlogs, veneer logs, etc.). Those rankings are assumed to reflect market value of timber products. To produce stand-level estimates, output from the software can be linked with most operational timber cruising software applications that generate tree-species-specific data, such as breast height diameter, tree total height (measured or estimated), and number of trees of a given size per unit area. As well, guidance is provided for using the software.

- Zhang, Y.Q., J.M. Chen, J.R. Miller and T.L. Noland. 2008. **Leaf chlorophyll content retrieval from airborne hyperspectral remote sensing imagery.** Remote Sens. Environ. 112(7): 3234-3247.

Hyperspectral remote sensing has great potential for accurate retrieval of forest biochemical parameters. In this paper, the authors report on a hyperspectral remote sensing algorithm developed to retrieve total leaf chlorophyll content for both open spruce and closed forests, and tested for open forest canopies. Ten black spruce stands near Sudbury, Ontario, Canada, were selected as study sites, where extensive field and laboratory measurements were carried out to collect forest structural parameters, needle and forest background optical properties, and needle biophysical parameters and biochemical contents chlorophyll

a and b. Airborne hyperspectral remote sensing imagery was acquired within one week of ground measurements using the Compact Airborne Spectrographic Imager (CASI) in a hyperspectral mode, with 72 bands and half bandwidth 4.25-4.36 nm in the visible and near-infrared region and a 2 m spatial resolution. The geometrical-optical model 4-Scale and the modified leaf optical model PROSPECT were combined to estimate leaf chlorophyll content from the CASI imagery. Forest canopy reflectance was first estimated with the measured leaf reflectance and transmittance spectra, forest background reflectance, CASI acquisition parameters, and a set of stand parameters as inputs to 4-Scale. The estimated canopy reflectance agrees well with the CASI measured reflectance in the chlorophyll absorption sensitive regions, with discrepancies of 0.06%-1.07% and 0.36%-1.63%, respectively, in the average reflectances of the red and red-edge region. A look-up-table approach was developed to provide the probabilities of viewing the sunlit foliage and background, and to determine a spectral multiple scattering factor as functions of leaf area index, view zenith angle, and solar zenith angle. With the look-up tables, the 4-Scale model was inverted to estimate leaf reflectance spectra from hyperspectral remote sensing imagery. Agreement was obtained between the inverted and measured leaf reflectance spectra across the visible and near-infrared region, with $R^2 = 0.89$ to $R^2 = 0.97$ and discrepancies of 0.02%-3.63% and 0.24%-7.88% in the average red and red-edge reflectances, respectively. Leaf chlorophyll content was estimated from the retrieved leaf reflectance spectra using the modified PROSPECT inversion model, with $R^2 = 0.47$, $RMSE = 4.34 \mu\text{g}\cdot\text{cm}^{-2}$, and jackknifed $RMSE$ of $5.69 \mu\text{g}\cdot\text{cm}^{-2}$ for needle chlorophyll content ranging from $24.9 \mu\text{g}\cdot\text{cm}^{-2}$ to $37.6 \mu\text{g}\cdot\text{cm}^{-2}$. The estimates were also assessed at leaf and canopy scales using chlorophyll spectral indices TCARI/OSAVI and MTCI. An empirical relationship of simple ratio derived from the CASI imagery to the ground-measured leaf area index was developed ($R^2=0.88$) to map leaf area index. Canopy chlorophyll content per unit ground surface area was estimate, based on the spatial distributions of leaf chlorophyll content per unit leaf area and the leaf area index.

Zhang, Y.Q., J.M. Chen, J.R. Miller and T.L. Noland. 2008. **Retrieving chlorophyll content in conifer needles from hyperspectral measurements.** *Can. J. Remote Sens.* 34(3): 296-310.

Spectrally continuous hyperspectral data can be used to detect subtle features in the leaf optical spectra, which correlate especially well with major leaf pigments such as the leaf chlorophyll content. Extensive field and laboratory measurements were carried out at 10 sites in black spruce forests near Sudbury, Canada, to collect leaf optical spectra, leaf pigment contents, and leaf biophysical parameters. Black spruce needles sampled from different sites, age classes, and branch orientations varied in both optical properties and chlorophyll contents. The leaf optical model PROSPECT was modified to incorporate the edge effects of needles on light transfer through them. Two leaf biophysical parameters, namely needle width and thickness, were introduced into the model to account for the effects of leaf morphology on chlorophyll content retrieval. With the modifications to PROSPECT, the model can be used to capture the variability of needle optical properties and chlorophyll content from the measurements. Retrieval of needle chlorophyll content was improved with an accuracy of $R^2 = 0.59$ and root mean squared error of $RMSE = 6.32 \mu\text{g}\cdot\text{cm}^{-2}$ compared with the original PROSPECT model with an accuracy of $R^2 = 0.31$ and $RMSE = 9.51 \mu\text{g}\cdot\text{cm}^{-2}$.

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Appendix III. Forest Research Reports

- 101 **Anderson, H.W. and L. Zsuffa.** 1975. Yield and wood quality of hybrid cottonwood grown in two-year rotation. Ont. Min. Nat. Resour., For. Res. Branch, For. Res. Rep. No. 101. 35 p.
- 102 **Kemperman, J.A., N.F. Lyon and S. Navratil.** 1976. Incidence and volume of defect in second growth aspen stands in northern Ontario. Ont. Min. Nat. Resour., For. Res. Branch, For. Res. Rep. No. 102. 24 p.
- 103 **Anderson, H.W. and L. Zsuffa.** 1977. Farming hybrid poplar for food and fibre: An exploratory study of the seasonal above-ground biomass. Ont. Min. Nat. Resour., For. Res. Branch, For. Res. Rep. No. 103. 8 p.
- 104 **Kemperman, J.A., S. Navratil and J.T. Basham.** 1978. Preliminary assessment of defect variation among aspen clones in northern Ontario. Ont. Min. Nat. Resour., Ont. For. Res. Cent., For. Res. Rep. No. 104. 9 p.
- 105 **Skeates, D.A. and V.H.H. Williamson.** 1979. Black spruce germinant transplants: The use of pregerminated seed in bare root transplant production. Ont. Min. Nat. Resour., Ont. For. Res. Cent., For. Res. Rep. No. 105. 15 p.
- 106 **Raymond, F.L.** 1980. INREG: An interactive computer program for multiple linear regression by least squares. Ont. Min. Nat. Resour., Ont. For. Res. Cent., For. Res. Rep. No. 106. 21 p.
- 107 **Stroempl, G.** 1983. Growth response of basswood and sugar maple to an intermediate cutting. Ont. Min. Nat. Resour., Ont. Tree Improv. For. Biomass Inst., For. Res. Rep. No. 107. 19 p.
- 108 **Beckwith, A.F., P. Roebbelen and V.G. Smith.** 1983. Red pine plantation growth and yield tables. Ont. Min. Nat. Resour., Ont. Tree Improv. For. Biomass Inst., For. Res. Rep. No. 108. 70 p.
- 109 **vanBorrendam, W.** 1984. Identification of remnant white spruce in southern Ontario: A basis for gene conservation. Ont. Min. Nat. Resour., Ont. Tree Improv. For. Biomass Inst., For. Res. Rep. No. 109. 20 p.
- 110 **Colombo, S.J., D.P. Webb and C. Glerum.** 1984. Frost hardiness testing: An operational manual for use with Extended Greenhouse Culture. Ont. Min. Nat. Resour., Ont. Tree Improv. For. Biomass Inst., For. Res. Rep. No. 110. 14 p.
- 111 **Weingartner, D.H. and J.T. Basham.** 1985. Variations in the growth and defect of aspen (*Populus tremuloides* Michx.) clones in Northern Ontario. Ont. Min. Nat. Resour., Ont. Tree Improv. For. Biomass Inst., For. Res. Rep. No. 111. 26 p.
- 112 **Pelkonen, P. and C. Glerum.** 1985. Poplar clonal variation in frost hardiness and electrical impedance during the fall. Ont. Min. Nat. Resour., Ont. Tree Improv. For. Biomass Inst., For. Res. Rep. No. 112. 12 p.
- 113 **Maurer, N.L., G.D. Racey and R.E. Hutchison.** 1985. The Dunemann option: Small-scale production of tree seedlings. Ont. Min. Nat. Resour., Ont. Tree Improv. For. Biomass Inst., For. Res. Rep. No. 113. 16 p.
- 114 **Bates, D.N. and D.L. Gillmeister (eds.).** 1986. Ontario Tree Improvement and Forest Biomass Institute publications: 1980-1985. (An annotated bibliography). Ont. Min. Nat. Resour., Ont. Tree Improv. For. Biomass Inst., For. Res. Rep. No. 114. 31 p.
- 115 **Racey, G.D. and G.R. Sanguins.** 1987. An evaluation of sprayable latex mulches in some forestry applications. Ont. Min. Nat. Resour., Ont. Tree Improv. For. Biomass Inst., For. Res. Rep. No. 115. 9 p.
- 116 **Colombo, S.J. and W.A. Smith.** 1988. Response of containerized black spruce and jack pine seedlings to fertilization rate and growing medium. Ont. Min. Nat. Resour., Ont. Tree Improv. For. Biomass Inst., For. Res. Rep. No. 116. 15 p.
- 117 **Stroempl, G.** 1987. Growth and quality of red oak planted in red pine plantation openings. Ont. Min. Nat. Resour., Ont. Tree Improv. For. Biomass Inst., For. Res. Rep. No. 117. 6 p.
- 118 **Racey, G.D.** 1988. Cold temperature conditioning of conifer seedlings prior to frozen overwinter storage. Ont. Min. Nat. Resour., Ont. Tree Improv. For. Biomass Inst., For. Res. Rep. No. 118. 7 p.
- 119 **Skeates, D.A. and V.F. Haavisto.** 1987. Black spruce cone and seed production: Yields from Ontario collections. Ont. Min. Nat. Resour., Ont. Tree Improv. For. Biomass Inst., For. Res. Rep. No. 119. 16 p. + append.
- 120 **Racey, G.D.** 1987. Moisture retaining materials for tree seedling packaging: A literature review. Ont. Min. Nat. Resour., Ont. Tree Improv. For. Biomass Inst., For. Res. Rep. No. 120. 16 p.

- 121 **Racey, J.E. and G.D. Racey.** 1988. Undercutting and root wrenching of tree seedlings: An annotated bibliography. Ont. Min. Nat. Resour., Ont. Tree Improv. For. Biomass Inst., For. Res. Rep. No. 121. 79 p.
- 122 **Skeates, D.A. and D.E. Irving.** 1988. Nursery indications of white spruce provenance variability in northwestern Ontario. Ont. Min. Nat. Resour., Ont. Tree Improv. For. Biomass Inst., For. Res. Rep. No. 122. 13 p.
- 123 **Raymond, F.L.** 1989. Dimensional growth, difference-based equations and growth predictions. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Rep. No. 123. 19 p.
- 124 **Racey, G.D., C. Glerum and R.E. Hutchison.** 1989. Interaction of stock type and site with three coniferous species. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Rep. No. 124. 12 p.
- 125 **Ho, R.H.** 1991. A guide to pollen- and seed-cone morphology of black spruce, white spruce, jack pine and eastern white pine for controlled pollination. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Rep. No. 125. 31 p.
- 126 **MacDonald, G.B.** 1991. A comparison of new proximity-based expressions of competing vegetation. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Rep. No. 126. 17 p.
- 127 **Paterson, J.M.** 1991. Field performance of black spruce container stock. Number 1. Comparison of two growing environments and four container types: Second-year field results from 1989 outplanting. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Rep. No. 127. 10 p.
- 128 **Templeton, C.W.G., S.J. Colombo and K.D. Odum.** 1993. Effect of short-term storage of shoot tips from black spruce container seedlings on the estimation of bud initiation and needle primordia number. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Rep. No. 128. 7 p.
- 129 **Burger, D.** 1993. Revised site regions of Ontario: Concepts, methodology and utility. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Rep. No. 129. 24 p.
- 130 **Paterson, J.M. and D.S. Maki.** 1994. Effect of initial seedling morphology and planting practices on field performance of jack pine 6 years after planting. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Rep. No. 130. 15 p.
- 131 **Guyette, R.P. and D.C. Dey.** 1995. Age, size and regeneration of old growth white pine at Dividing Lake Nature Reserve, Algonquin Park, Ontario. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Rep. No. 131. 11 p.
- 132 **Guyette, R.P. and D.C. Dey.** 1995. A presettlement fire history in an oak-pine forest near Basin Lake, Algonquin Park, Ontario. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Rep. No. 132. 7 p.
- 133 **Guyette, R.P., D.C. Dey and C. McDonell.** 1995. Determining fire history from old white pine stumps in an oak-pine forest in Bracebridge, Ontario. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Rep. No. 133. 9 p.
- 134 **Guyette, R.P. and D.C. Dey.** 1995. A dendrochronological fire history of Opeongo Lookout in Algonquin Park, Ontario. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Rep. No. 134. 4 p.
- 135 **Ho, R.H., O. Hak, M.H. Laine and R.D. Ford.** 1996. Promotion of pollen-cone production by heat treatment and naphthalene acetic acid spraying in potted black spruce. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Rep. No. 135. 12 p.
- 136 **Hak, O.** 1996. Vacuum processing and storage of spruce pollen. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Rep. No. 136. 6 p.
- 137 **Gluck, M., R. Rempel and P.W.C. Uhlig.** 1996. An evaluation of remote sensing for regional wetland mapping applications. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Rep. No. 137. 33 p.
- 138 **Ho, R.H.** 1996. Promotion of cone production on field-grown grafts of eastern white pine by gibberellin A4/7 injection. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Rep. No. 138. 6 p.
- 139 **Cumming, H.G., R.A. Lautenschlager, C.P. Kelly and S. Thapa.** 1996. Effects of conifer release with Vision (glyphosate) herbicide on moose forage quality (digestible protein). Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Rep. No. 139. 8 p.
- 140 **Dey, D.C. and R.P. Guyette.** 1996. Fire history near an historic travel corridor in Ontario. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Rep. No. 140. 9 p.

- 141 **Anderson, H.W. and J.A. Rice.** 1996. Quality assurance in hardwood tree marking: A case study. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Rep. No. 141. 14 p.
- 142 **Mohammed, G.H. and T.L. Noland.** 1997. Influence of time of day and sampling methodology on chlorophyll fluorescence in jack pine (*Pinus banksiana* Lamb.), black spruce (*Picea mariana* (Mill.) B.S.P.), and eastern white pine (*Pinus strobus* L.). Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Rep. No. 142. 14 p.
- 143 **Kim, Y.T., C. Glerum, D.F. Hickie and C.P. Chen.** 1997. Effects of cold storage duration on carbohydrate and amino acid concentration, root growth potential, and growth of jack pine and black spruce seedlings. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Rep. No. 143. 18 p.
- 144 **Ter-Mikaelian, M.T., W.C. Parker and J.M. Paterson.** 1997. Photo imagery: A non-destructive method for estimating tree biomass. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Rep. No. 144. 10 p.
- 145 **Smith, W. and G.H. Mohammed.** 1997. Inoculation with mycorrhizal fungi (*Hebeloma* spp.) can increase drought stress resistance and improve field performance of jack pine, black spruce, and white spruce. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Rep. No. 145. 10 p.
- 146 **Perera, A.H., D.J.B. Baldwin and F. Schneckeburger.** 1997. LEAP II: A landscape ecological analysis package for land use planners and managers. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Rep. No. 146. 88 p.
- 147 **Perera, A.H., D.J.B. Baldwin, F. Schneckeburger, J.E. Osborne and R.E. Bae.** 1999. Forest fires in Ontario: A spatio-temporal perspective. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Rep. No. 147. 22 p.
- 148 **Kenkel, N.C., P.R. Watson and P.W.C. Uhlig.** 1998. Modelling landscape-level vegetation dynamics in the boreal forests of northwestern Ontario. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Rep. No. 148. 151 p.
- 149 **Band, L.E., F. Csillag, A.H. Perera and J.A. Baker.** 1999. Deriving an eco-regional framework for Ontario through large-scale estimates of net primary productivity. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Rep. No. 149. 30 p.
- 150 **Baldwin, D.J.B., K. Weaver, F. Schneckeburger and A.H. Perera.** 2001. Sensitivity of landscape pattern indices to spatial extent, data resolution, and classification detail in the managed forest of Ontario. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Rep. No. 150. 45 p.
- 151 **Baldwin, D.J.B., L.E. Band and A.H. Perera.** 1998. A quantitative basis for using Ontario's existing ecoregionalization systems. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Rep. No. 151. 70 p.
- 152 **Perera, A.H., M. Ouellette, W. Cui, M. Drescher and D. Boychuck.** 2008. BFOLDS 1.0: A spatial simulation model for exploring large scale fire regimes and succession in boreal forest landscapes. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Rep. No. 152. 50 p.
- 153 **Greifenhagen, S. and M. Cherry.** 2005. Estimating decay in living trees: An assessment of two decay detection instruments. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Rep. No. 153. 9 p. + append.
- 154 **Candau, J.-N.** 2002. Bioclimatic analysis of declining aspen stands in northeastern Ontario. Ont. Min. Nat. Resour., Ont. For. Res. Inst., Sault Ste. Marie, ON. For. Res. Rep. No. 154. 16 p.
- 155 **Peng, C.H.** 1999. Nonlinear height-diameter models for nine boreal forest tree species in Ontario. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Rep. No. 155. 28 p.
- 156 **Mohammed, G.H., T.L. Noland, D. Irving, P.H. Sampson, P.J. Zarco-Tejada and J.R. Miller.** 2000. Natural and stress-induced effects on leaf spectral reflectance in Ontario species. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Rep. No. 156. 34 p.
- 157 **MacDonald, G.B.** 2000. Harvesting boreal mixedwood stands to favour conifer regeneration: Project establishment and early results. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Rep. No. 157. 20 p.
- 158 **Peng, C.H., J. Liu, M. Apps, Q. Dang and W. Kurz.** 2000. Quantifying Ontario's forest carbon budget I. Carbon stocks and fluxes of forest ecosystems in 1990. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Rep. No. 158. 20 p.
- 159 **Peng, C., L. Zhang, S. Huang, X. Zhou, J. Parton and M. Woods.** 2001. Developing ecoregion-based height-diameter models for jack pine and black spruce in Ontario. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Rep. No. 159. 10 p.

- 160 **Cherry, M.** and W.H. Parker. 2003. Utilization of genetically improved stock to increase carbon sequestration. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Rep. No. 160. 15 p.
- 161 Timmer, V.R. and Y. Teng. 2003. Increasing carbon sequestration through enhanced stand establishment practices: Nursery nutrient loading. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Rep. No. 161. 15 p.
- 162 **MacDonald, G.B.** and J. Elliott. 2003. Applying crown and bole allometry to management of boreal mixedwood species. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Rep. No. 162. 13 p.
- 163 Zhou, X, **C. Peng**, Q. Dang, J. Chen and S. Parton. 2004. Simulating forest growth and carbon dynamics of the Lake Abitibi Model Forest in northeastern Ontario. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Rep. No. 163. 20 p.
- 164 **Chapman, K.A.** and **W.G. Cole**. 2006. Testing large-scale photography to sample plots for forest inventory in mixed and hardwood forests of the Great Lakes-St. Lawrence region of Ontario. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Rep. No. 164. 22 p.
- 165 **Drescher, M., A.H. Perera, L.J. Buse**, K. Ride, and S. Vasiliauskas. 2006. Identifying uncertainty in practitioner knowledge of boreal forest succession in Ontario through a workshop approach. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Rep. No. 165. 53 p.
- 166 Pinto, F., **M. Ter-Mikaelian J.-M. Sobze** and D. Rouillard. 2007. A method to validate stand attributes in a forest resource inventory: Case study in Nipissing Forest, Ontario. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Rep. No. 166. 10 p. + append.
- 167 **Cui, W.** and **A.H. Perera**. 2008. A study of simulation errors caused by algorithms of forest fire growth models. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Rep. No. 167. 17 p.
- 168 **Perera, A.H., L.J. Buse**, R.G. Routledge, **B.D. Dalziel** and **T. Smith**. 2008. An assessment of tree, snag, and downed wood residuals in boreal fires in relation to Ontario's policy directions for emulating natural forest disturbance. Ont. Min. Nat. Resour., Ont. For. Res. Inst., Sault Ste. Marie, ON. For. Res. Rep. No. 168. 59 p. + append.
- 169 **Perera, A.H., T.K. Rimmel, L.J. Buse** and **M.R. Ouellette**. 2009. An assessment of residual patches in boreal fires in relation to Ontario's policy directions for emulating natural disturbance. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Rep. No. 169. 65 p. + append.
- 170 **Perera, A.H., W. Cui** and **M.R. Ouellette**. 2009. Size class distribution and spatial proximity of fires in a simulated boreal forest fire regime in relation to Ontario's policy directions for emulating natural disturbance. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Rep. No. 170. 29 p.
- 171 **Drescher, M., A.H. Perera, L.J. Buse**, R. Arnup, C. Bowling, D. Etheridge, G. Niznowski, K. Ride and S. Vasiliauskas. 2008. Boreal forest succession in Ontario: An analysis of the knowledge space. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Rep. No. 171. 51 p. + append.
- 172 **Noland, T.** and M. Abou-Zaid. 2008. Canada yew: Developing a value-added crop for northern Ontario. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Rep. No. 172. 19 p. + append.
- 173 **Cui, W., M.R. Ouellette, A.H. Perera** and M. Gluck. 2009. Using BFOLDS to characterize fire regimes: A case study from a boreal forest landscape. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Rep. No. 173. 41 p.

Appendix IV. Forest Research Information Papers

- 101 **Kemperman, J.A.** 1977. Aspen clones: Development, variability, and identification. Ont. Min. Nat. Resour., For. Res. Branch, For. Res. Inf. Pap. No. 101. 11 p.
- 102 **Fayle, D.C.F., L. Zsuffa and H.W. Anderson** (eds.). 1979. Poplar research, management and utilization in Canada. Proc. N. Am. Poplar Counc. Annu. Meet., Brockville, Ont., 6-9 Sept. 1977. Ont. Min. Nat. Resour., Ont. For. Res. Cent., For. Res. Inf. Pap. No. 102. 255 p.
- 103 **Larsson, H.C.** 1982. A silvicultural planting key for lowland sites in southern Ontario. Ont. Min. Nat. Resour., Ont. Tree Improv. For. Biomass Inst., For. Res. Inf. Pap. No. 103. 35 p.
- 104 **Stroeml, G.** 1984. Thinning clumps of northern hardwood stump sprouts to produce high quality timber. Ont. Min. Nat. Resour., Ont. Tree Improv. For. Biomass Inst., For. Res. Inf. Pap. No. 104. 27 p.
- 105 **Mohammed, G.H.** 1991. Forest renewal research and development needs survey. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Inf. Pap. No. 105. 20 p.
- 106 **Bates, D.N. and D.L. Gillmeister.** 1992. Ontario Forest Research Institute Publications 1980-1991 (An annotated bibliography). Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Inf. Pap. No. 106. 74 p.
- 107 **Hills, S.C. and D.M. Morris.** 1992. The function of seed banks in northern forest ecosystems (A literature review). Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Inf. Pap. No. 107. 25 p.
- 108 **Harvey, E.M., G.H. Mohammed and T.L. Noland.** 1993. A bibliography on competition, tree seedling characteristics, and related topics. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Inf. Pap. No. 108. 117 p.
- 109 **Gordon, A.G., D.M. Morris and N. Balakrishnan.** 1993. Impacts of various levels of biomass removals on the structure, function, and productivity of black spruce ecosystems: Research protocols. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Inf. Pap. No. 109. 21 p.
- 110 **Elliott, J.A., D.M. Morris and J.L. Kantor.** 1993. Studying successional pathways in forest communities: An annotated bibliography. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Inf. Pap. No. 110. 320 p.
- 111 **Lautenschlager, R.A.** 1993. Effects of conifer release with herbicides on wildlife (A review with an emphasis on Ontario's forests). Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Inf. Pap. No. 111; VMAP Tech. Rep. No. 93-11. 23 p.
- 112 **Uhlig, P.W.C. and J. Baker.** 1994. Provincial Ecological Land Classification Program Prospectus. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Inf. Pap. No. 112. 15 p.
- 113 **Anderson, H.W. and A.G. Gordon.** 1994. The tolerant conifers: Eastern hemlock and red spruce, their ecology and management. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Inf. Pap. No. 113. 41 p.
- 114 **Fawcett, R. and J.M. Paterson.** 1994. Portable root wash station. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Inf. Pap. No. 114. 5 p.
- 115 **Cole, W.G. and A.M. Gordon.** 1995. Long-term Ecological Research Program: Strategic plan. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Inf. Pap. No. 115. 18 p.
- 116 **MacDonald, G.B. and D.H. Weingartner.** 1994. A prospectus for the Mixedwood Silviculture Program at the Ontario Forest Research Institute. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Inf. Pap. No. 116. 16 p.
- 117 **Rice, J.A. (ed.).** 1994. Logging damage: The problems and practical solutions. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Inf. Pap. No. 117. 69 p.
- 118 **Weingartner, D.H. and G.B. MacDonald.** 1994. A survey of mixedwood research and development needs in Ontario. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Inf. Pap. No. 118. 17 p.
- 119 **Guyette, R.P. and D.C. Dey.** 1995. A history of fire, disturbance, and growth in a red oak stand in the Bancroft District, Ontario. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Inf. Pap. No. 119. 14 p.

- 120 **Stroempl, G.** and P.W. Secker. 1995. Guide to the group shelterwood cutting method for regenerating northern red oak. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Inf. Pap. No. 120. 45 p.
- 121 **Kerley, J.G.,** D. Carr, T. Kenedi and J. Hallam. 1995. Ontario Growth and Yield Program: Quality assurance procedures for permanent sample plots. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Inf. Pap. No. 121. 9 p.
- 122 **Dey, D.C.** and M. Buchanan. 1995. Red oak (*Quercus rubra* L.) acorn collection, nursery culture and direct seeding: A literature review. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Inf. Pap. No. 122. 46 p.
- 123 Newmaster, S.G., A. Lehela, P.W.C. Uhlig, S. McMurray and M.J. Oldham. 1998. Ontario plant list. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Inf. Pap. No. 123. 550 p. + append.
- 124 **Bankowski, J., D.C. Dey, M. Woods, J.A. Rice, E. Boysen, B. Batchelor and R.J. Miller.** 1995. Validation of FIBER 3.0 for tolerant hardwood stands in Ontario. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Inf. Pap. No. 124. 32 p.
- 125 **Gillmeister, D.L., L.J. Buse and D. Bates.** 1996. Ontario Forest Research Institute publications 1990-1995: An annotated bibliography. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Inf. Pap. No. 125. 85 p.
- 126 **Dey, D.C. and W.C. Parker.** 1996. Regeneration of red oak (*Quercus rubra* L.) using shelterwood systems: Ecophysiology, silviculture, and management recommendations. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Inf. Pap. No. 126. 59 p.
- 127 **Dey, D.C.** 1995. Acorn production in red oak. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Inf. Pap. No. 127. 22 p.
- 128 **Bankowski, J., D. Dey, M. Woods, J. Rice, E. Boysen and R. Miller.** 1995. Validation of SILVAH for tolerant hardwoods in Ontario. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Inf. Pap. No. 128. 28 p.
- 129 **Lautenschlager, R.A.** 1995. Biodiversity conservation research needs (Obstacles to biodiversity research). Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Inf. Pap. No. 129. 25 p.
- 130 **Bankowski, J., D. Dey, E. Boysen, M. Woods and J. Rice.** 1996. Validation of NE-TWIGS for tolerant hardwood stands in Ontario. Ont. Min. Nat. Res., Ont. For. Res. Inst., For. Res. Inf. Pap. No. 130. 21 p.
- 131 Johnson, F., J. Paterson, G. Leeder, C. Mansfield, F. Pinto and S. Watson. 1996. Artificial regeneration of Ontario's forests: Species and stock selection manual. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Inf. Pap. No. 131. 49 p. + append.
- 132 **Menes, P.A., K.D. Odium and J.M. Paterson.** 1996. Comparative performance of bareroot and container-grown seedlings: An annotated bibliography. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Inf. Pap. No. 132. 151 p.
- 134 Kennedy, J., E.M. Harvey and W.C. Parker. 1996. Natural regeneration of Ontario's major commercial coniferous species: A bibliography. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Inf. Pap. No. 134. 106 p.
- 135 Hayes, A.E. and W.G. Cole. (eds.). 1996. Long-term Ecological Research Program: 1995 annual report. Ont. Min. Nat. Resour., Ont. For. Res. Inst., Sault Ste. Marie, ON., For. Res. Inf. Pap. No. 135. 26 p.
- 136 **Lautenschlager, R.A.** and M.H.R. Browning. 1997. OMNR Science Forum 1996 – An ecosystem approach to ecological sustainability. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Inf. Pap. No. 136. 11 p. + append.
- 137 **Mohammed, G.H., P.H. Sampson, S.J. Colombo, T.L. Noland and J.R. Miller.** 1997. Bioindicators of forest sustainability: Development of a forest condition rating system for Ontario. *Project strategy*. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Inf. Pap. No. 137. 22 p.
- 138 Fogal, W., T.C. Hutchinson and A.M. Thruscutt. 1997. Bioindicators of forest health and sustainability - Review report and project implementation strategies. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Inf. Pap. No. 138. 88 p. + append.
- 139 **MacDonald, G.B.,** R. Arnup and R.K. Jones. 1997. Adaptive forest management in Ontario: A literature review and strategic analysis. Ont. Min. Nat. Res., Ont. For. Res. Inst., For. Res. Inf. Pap. No. 139. 38 p.
- 140 **Cole, W. G.,** T. Gillis and W. Ripmeester. 1998. Swan Lake Forest Research Reserve geographic information system — User's guide. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Inf. Pap. No. 140. 14 p. + append.
- 141 **Wagner, R.G.** and D.G. Thompson. (comp.). 1998. Third International Conference on Forest Vegetation Management: Popular summaries. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Inf. Pap. No. 141. 508 p.

FOREST RESEARCH INFORMATION PAPER

- 141A Pitt, D.G. and F.W. Bell. (comp.). 1998. Third International Conference on Forest Vegetation Management: In-conference tour guide. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Inf. Pap. No. 141A. 140 p.
- 142 Sampson, P.H., G.H. Mohammed, S.J. Colombo, T.L. Noland, J.R. Miller and P.J. Zarco-Tejada. 1998. Bioindicators of forest sustainability: Progress report. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Inf. Pap. No. 142. 18 p.
- 143 Colombo, S.J., M.L. Cherry, C. Graham, S. Greifenhagen, R.S. McAlpine, C.S. Papadopol, W.C. Parker, T. Scarr and M.T. Ter-Mikaelian. 1998. The impacts of climate change on Ontario's forests. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Inf. Pap. No. 143. 50 p.
- 144 Cole, W.G., E.C. Mallory and D.N. Niblett. 1999. Swan Lake Forest Research Reserve - Annotated bibliography 1955-1999. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Inf. Pap. No. 144. 57 p.
- 145 Mohammed, G.H. 1999. Non-timber forest products in Ontario: An overview. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Inf. Pap. No. 145. 64 p.
- 146 Yemshanov, D. and A.H. Perera. 2001. Modelling boreal forest succession at broad scales: A North American bibliography. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Inf. Pap. No. 146. 46 p.
- 147 Buse, L.J. 2001. Ontario Forest Research Institute publications 1996-2000: A bibliography with abstracts. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Inf. Pap. No. 147. 105 p.
- 148 Cherry, M. 2001. Options for allocating afforestation stock in Ontario with anticipated climate change. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Inf. Pap. No. 148. 29 p.
- 149 Buse, L.J. and A.H. Perera. (comp.). 2002. Emulating natural forest landscape disturbances: Concepts and applications *Popular summaries*. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Inf. Pap. No. 149. 100 p.
- 150 Yemshanov, D. and A.H. Perera. 2002. Early recruitment of tree species: a knowledge gap in landscape dynamics modelling. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Inf. Pap. No. 150. 22 p.
- 151 Mohammed, G.H. 2002. Forest genetics and tree improvement in Ontario: Synopsis of a science workshop. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Inf. Pap. No. 151. 13 p.
- 152 Cole, W.G., D.I. Farintosh and J.L. Todd. 2005. Ontario hardwood silviculture studies database: Metadata report. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Inf. Pap. No. 152. 154 p.
- 153 Cole, W.G., D.L. Farintosh, J.L. Todd and E.C. Mallory. 2003. Ontario hardwood silviculture studies database: Annotated bibliography. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Inf. Pap. No. 153. 86 p.
- 154 Greifenhagen, S. and T.L. Noland. (comp.). 2003. A synopsis of known and potential diseases and parasites associated with climate change. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Inf. Pap. No. 154. 182 p.
- 155 Buse, L.J. and A.H. Perera. (comp.). 2003. Meeting emerging ecological, economic, and social challenges in the Great Lakes region: *Popular summaries*. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Inf. Pap. No. 155. 206 p.
- 156 Schneckeburger, F. and A.H. Perera. 2003. Regional-scale forest net primary productivity assessment software (NPPAS): A user's guide. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Inf. Pap. No. 156. 26 p.
- 157 MacDonald, G.B., J.A. Rice, J. McLaughlin, J. Pearce, L. Venier, K. Nystrom and P. Meek. 2003. Developing sustainable mixedwood practices in a stand-level adaptive management (SLAM) framework: Project establishment. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Inf. Pap. No. 157. 17 p.
- 158 McLaughlin, J. 2004. Carbon assessment in boreal wetlands of Ontario. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Inf. Pap. No. 158. 79 p.
- 159 Perera, A.H., L.J. Buse and R.G. Routledge. 2004. An analysis of literature on natural fire disturbances in relation to Ontario's Forest Management Guide for Natural Disturbance Pattern Emulation. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Inf. Pap. No. 159. 62 p.
- 160 Colombo, S.J. (comp.). 2005. The Thin Green Line: A symposium on the state-of-the-art in reforestation *Proceedings*. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Inf. Pap. No. 160. 175 p.

- 161 Gleeson, J., A. Zeller and J.W. McLaughlin. 2006. Peat as a fuel source in Ontario: A preliminary literature review. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Inf. Pap. No. 161. 23 p. + append.
- 162 Buse, L.J. 2006. Ontario Forest Research Institute publications 2001-2005: An annotated bibliography. (comp.). Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Inf. Pap. No. 162. 49 p. + append.
- 163 Cui, W. and A.H. Perera. 2006. Forest fire size distribution in North American boreal forests: A state of knowledge. Ont. Min. Nat. Resour., Ont. For. Res. Inst., Sault Ste. Marie, ON. For. Res. Inf. Pap. No. 163. 22 p.
- 164 Perera, A.H. and L.J. Buse. 2006. Multiple-scale research studies on boreal forest fire regimes to inform Ontario's policies for emulating natural forest disturbances: A prospectus. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Inf. Pap. No. 164. 24 p + append.
- 165 Sobze, J.-M., M.T. Ter-Mikaelian and S.J. Colombo. 2006. Wood supply in Ontario: The road to better prediction. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Inf. Pap. No. 165. 11 p. + append.
- 166 McLaughlin, J.W. 2007. Forest Soil and Water Research Program five-year research strategy 2006-2011. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Inf. Pap. No. 166. 30 p. + append.
- 167 Newton, P.F. and V.M. LeMay (cochairs). 2007. Complex stand structures and associated dynamics: Measurement indices and modelling approaches. Popular summaries. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Inf. Pap. No. 167. 117 p.
- 168 Perera, A.J., L.J. Buse and R.G. Routledge. 2007. A review of published knowledge on post-fire residuals relevant to Ontario's policy directions for emulating natural disturbance. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Inf. Pap. No. 168. 37 p. + append.
- 169 Routledge, R.G. 2007. Sampling methodology for studying boreal post-fire residual stand structure with high resolution aerial photography and field plots. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Inf. Pap. No. 169. 37 p. + append.
- 170 Smith, T., B. Datzel and R.G. Routledge. 2008. A proposed method to rank the intensity of boreal forest fires in Ontario using post-fire high resolution aerial photographs. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Inf. Pap. No. 170. 23 p.
- 171 Ouellette, M. 2008. BFOLDS 1.0: A user's guide to the software package (Version 1.0.0). Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Inf. Pap. No. 171. 68 p. (electronic only)
- 172 Smith, G.K.M. and L.J. Buse. 2008. Evolving challenges and changing expectations for forestry extension and technology transfer: Meeting the needs of people and forests around the globe. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Inf. Pap. No. 172. 74 p.
- 173 Ouellette, M. and M.D. Drescher. 2010. Succession Pathway Tool user's guide. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Info. Pap. No. 173. 39 p. + append.
- 174 Zakrzewski, W.T., F. Schnekenburger and P. Kozlowski. 2010. Tools for optimizing timber product mix: User's guide for Visualizer-Buck. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Inf. Pap. No. 174. 18 p. + append.

Appendix V. Forest Research Notes

- 1 **Mullin, R.E.** and K. Blum. 1975. A test of containers and method of storage for spring lifting of nursery stock. Ont. Min. Nat. Resour., For. Res. Br., For. Res. Note No. 1. 3 p.
- 2 **Mullin, R.E.** 1975. Underplanting tests with red and white pine in southern Ontario. Ont. Min. Nat. Resour., For. Res. Br., For. Res. Note No. 2. 4 p.
- 3 **Mullin, R.E.** and L. Forcier. 1976. Effect of lifting and planting dates on survival and growth of spring stored nursery stock. Ont. Min. Nat. Resour., For. Res. Br., For. Res. Note No. 3. 4 p.
- 4 **Zsuffa, L.** and G.H. Saul. 1976. The rooting ability of winter stored and freshly planted cuttings of *Leuce Duby* (aspen) hybrid clones. Ont. Min. Nat. Resour., For. Res. Br., For. Res. Note No. 4. 4 p.
- 5 **Glerum, C., J.G. Boufford** and J.M. Paterson. 1976. Irregular growth of outplanted red pine. I. The influence of nursery herbicidal practices. Ont. Min. Nat. Resour., For. Res. Br., For. Res. Note No. 5. 4 p.
- 6 **Pierpoint, G., J.M. Paterson, J.G. Boufford** and C. Glerum. 1977. Irregular growth of outplanted red pine. (II) The influence of handling and planting on first-year performance. Ont. Min. Nat. Resour., For. Res. Br., For. Res. Note No. 6. 4 p.
- 7 **McClain, K.M.** 1977. Differential effects of seedbed density on seedling growth. Ont. Min. Nat. Resour., For. Res. Br., For. Res. Note No. 7. 4 p.
- 8 **Williamson, V.H.H.** 1977. Corrugated-plastic shelters for growing forest tree seedlings. Ont. Min. Nat. Resour., For. Res. Br., For. Res. Note No. 8. 4 p.
- 9 **Mullin, R.E.** and W.R. Bunting. 1977. A test of heeling-in to harden stock for frozen overwinter storage in polybags and Kraft bags. Ont. Min. Nat. Resour., For. Res. Br., For. Res. Note No. 9. 4 p.
- 10 **Mullin, R.E.** and R.E. Hutchison. 1977. Agricol, clay and water dipping tests with jack pine and black spruce nursery stock. Ont. Min. Nat. Resour., For. Res. Br., For. Res. Note No. 10. 3 p.
- 11 **Rauter, R.M.** 1977. Collection of spruce cuttings for vegetative propagation. Ont. Min. Nat. Resour., For. Res. Br., For. Res. Note No. 11. 4 p.
- 12 **Kemperman, J.A.** 1978. Sucker-root relationships in aspen. Ont. Min. Nat. Resour., Ont. For. Res. Cent., For. Res. Note No. 12. 4 p.
- 13 **Larsson, H.C.** and P. Jaciw. 1978. Potential for growing nut pines in Ontario. Ont. Min. Nat. Resour., Ont. For. Res. Cent., For. Res. Note No. 13. 4 p.
- 14 **Pierpoint, G., J.M. Paterson, J.G. Boufford** and C. Glerum. 1978. Irregular growth of outplanted red pine. III. The influence of handling and planting on second-year performance. Ont. Min. Nat. Resour., Ont. For. Res. Cent., For. Res. Note No. 14. 4 p.
- 15 **Mullin, R.E.** 1978. Plantation performance averages for white spruce. Ont. Min. Nat. Resour., Ont. For. Res. Cent., For. Res. Note No. 15. 2 p.
- 16 **Mullin, R.E.** 1978. Plantation performance averages for red pine. Ont. Min. Nat. Resour., Ont. For. Res. Cent., For. Res. Note No. 16. 2 p.
- 17 **Stroempl, G.** and A.F. Beckwith. 1978. A successful red oak-red pine plantation. Ont. Min. Nat. Resour., Ont. For. Res. Cent., For. Res. Note No. 17. 3 p.
- 18 **Mullin, R.E.** 1978. Plantation performance averages for white pine. Ont. Min. Nat. Resour., Ont. For. Res. Cent., For. Res. Note No. 18. 4 p.
- 19 **Mullin, R.E.** 1978. Plantation performance averages for black spruce. Ont. Min. Nat. Resour., Ont. For. Res. Cent., For. Res. Note No. 19. 3 p.
- 20 **Mullin, R.E.** 1979. Plantation performance averages for jack pine. Ont. Min. Nat. Resour., Ont. For. Res. Cent., For. Res. Note No. 20. 3 p.
- 21 **Zsuffa, L.** and K. Eng. 1979. Grafting and storage of fall-collected spruce and pine scions. Ont. Min. Nat. Resour., Ont. For. Res. Cent., For. Res. Note No. 21. 3 p.
- 22 **Glerum, C.** and J.G. Boufford. 1979. A comparison between top-root ratio determinations by oven-dry weight and volume displacement. Ont. Min. Nat. Resour., Ont. For. Res. Cent., For. Res. Note No. 22. 4 p.
- 23 **Glerum, C., J.G. Boufford** and J.M. Paterson. 1979. Irregular growth of outplanted red pine. V. A comparison between seedling and transplant stock. Ont. Min. Nat. Resour., Ont. For. Res. Cent., For. Res. Note No. 23. 4 p.

- 24 **Zsuffa, L.** and **T. Saul.** 1979. Rooting of trench-broadcasted short-cuttings of a poplar clone (*P. x euramericana* [Dode] Guinier c.v. I-45/51). Ont. Min. Nat. Resour., Ont. For. Res. Cent., For. Res. Note No. 24. 4 p.
- 25 **Lyon, N.F.** and **J.S. Thomson.** 1979. Jack pine ingress following aerial seeding. Ont. Min. Nat. Resour., Ont. For. Res. Cent., For. Res. Note No. 25. 4 p.
- 26 **Mullin, R.E.** 1980. Recent tests of seedlings versus transplants. Ont. Min. Nat. Resour., Ont. For. Res. Cent., For. Res. Note No. 26. 4 p.
- 27 **Stroempl, G.** 1980. Plastic netting to protect trees from animal damage. Ont. Min. Nat. Resour., Ont. For. Res. Cent., For. Res. Note No. 27. 4 p.
- 28 **McClain, K.M.** 1981. Effects of continuous planting on black spruce survival and growth: An interim report. Ont. Min. Nat. Resour., Ont. For. Res. Cent., For. Res. Note No. 28. 4 p.
- 29 **Pierpoint, G., J.M. Paterson, J.G. Boufford** and **C. Glerum.** 1981. Irregular growth of outplanted red pine. VI. The influence of handling and planting on fifth-year performance. Ont. Min. Nat. Resour., Ont. Tree Improv. For. Biomass Inst., For. Res. Note No. 29. 4 p.
- 30 **Skeates, D.A.** 1982. Cone collection tower. Ont. Min. Nat. Resour., Ont. Tree Improv. For. Biomass Inst., For. Res. Note No. 30. 4 p.
- 31 **vanBorrendam, W.** and **D.A. Skeates.** 1982. White spruce gene pool conservation in southern Ontario. Ont. Min. Nat. Resour., Ont. Tree Improv. For. Biomass Inst., For. Res. Note No. 31. 4 p.
- 32 **Colombo, S.J., C. Glerum** and **D.P. Webb.** 1982. Bud development in black spruce container stock. Ont. Min. Nat. Resour., Ont. Tree Improv. For. Biomass Inst., For. Res. Note No. 32. 5 p.
- 33 **Saul, G.H.** and **L. Zsuffa.** 1982. Vegetative propagation of alder (*Alnus glutinosa* L.) by rooted cuttings. Ont. Min. Nat. Resour., Ont. Tree Improv. For. Biomass Inst., For. Res. Note No. 33. 3 p.
- 34 **Saul, G.H.** and **L. Zsuffa.** 1983. The use of small scions and bare-root stock in grafting white pine. Ont. Min. Nat. Resour., Ont. Tree Improv. For. Biomass Inst., For. Res. Note No. 34. 3 p.
- 35 **Andison, D., P. Roebbelen** and **A.F. Beckwith.** 1984. Initial thinning in a semi-mature white and red pine stand. Ont. Min. Nat. Resour., Ont. Tree Improv. For. Biomass Inst., For. Res. Note No. 35. 4 p.
- 36 **Colombo, S.J.** 1984. Shoot morphology of winter-damaged black spruce container seedlings. Ont. Min. Nat. Resour., Ont. Tree Improv. For. Biomass Inst., For. Res. Note No. 36. 3 p.
- 37 **Colombo, S.J.** and **W.A. Smith.** 1984. Delayed bud initiation in black spruce container seedlings due to accidental daylength extension. Ont. Min. Nat. Resour., Ont. Tree Improv. For. Biomass Inst., For. Res. Note No. 37. 4 p.
- 38 **Colombo, S.J.** and **K.D. Odum.** 1984. Bud development in the 1982-83 overwintered black spruce container seedling crop. Ont. Min. Nat. Resour., Ont. Tree Improv. For. Biomass Inst., For. Res. Note No. 38. 4 p.
- 39 **Glerum, C.** and **J.M. Paterson.** 1985. A comparison between red pine seedlings and transplants five years after outplanting. Ont. Min. Nat. Resour., Ont. Tree Improv. For. Biomass Inst., For. Res. Note No. 39. 4 p.
- 40 **Racey, G.D., R.E. Hutchison** and **C. Glerum.** 1985. Performance of black spruce accelerated transplants after five years. Ont. Min. Nat. Resour., Ont. Tree Improv. For. Biomass Inst., For. Res. Note No. 40. 4 p.
- 41 **Racey, G.D.** 1985. Dissolved oxygen depletion by the roots of conifer seedlings during root soaking. Ont. Min. Nat. Resour., Ont. Tree Improv. For. Biomass Inst., For. Res. Note No. 41. 4 p.
- 42 **Colombo, S.J.** and **R.C. Cameron.** 1986. Assessing readiness of black spruce container seedlings for frozen storage using electrical impedance, oscilloscope square wave and frost hardness techniques. Ont. Min. Nat. Resour., Ont. Tree Improv. For. Biomass Inst., For. Res. Note No. 42. 6 p.
- 43 **Irving, D.E., K. Gashoka** and **D.A. Skeates.** 1987. Small-scale seed extractory. Ont. Min. Nat. Resour., Ont. Tree Improv. For. Biomass Inst., For. Res. Note No. 43. 4 p.
- 44 **Stroempl, G.** 1987. Growth and quality of red oak planted in a jack pine plantation. Ont. Min. Nat. Resour., Ont. Tree Improv. For. Biomass Inst., For. Res. Note No. 44. 4 p.
- 45 **Colombo, S.J.** and **D.F. Hickie.** 1987. A one-day test for determining frost hardness using the electrical conductivity technique. Ont. Min. Nat. Resour., Ont. Tree Improv. For. Biomass Inst., For. Res. Note No. 45. 4 p.
- 46 **O'Neill, G.J., M. Ditner** and **G.D. Racey.** 1988. Undercutting and wrenching of red pine, white pine and white spruce seedlings. Ont. Min. Nat. Resour., Ont. Tree Improv. For. Biomass Inst., For. Res. Note No. 46. 4 p.

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- 47 **Paterson, J.M. and R.E. Hutchison.** 1989. Red pine, white pine, white spruce stock type comparisons. Ont. Min. Nat. Resour., Ont. Tree Improv. For. Biomass Inst., For. Res. Note No. 47. 4 p.
- 48 **MacDonald, G.B.** 1991. Reliability of balsam fir growth and yield estimates based on black spruce normal yield tables. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Note No. 48. 4 p.
- 49 **Mohammed, G.H. and P.A. Menes.** 1992. Stem swelling and lesions on seedlings of black spruce and white spruce: A possible result of chemical injury? Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Note No. 49. 4 p.
- 50 **Templeton, C.W.G. and S.J. Colombo.** 1993. Egress of jack pine roots from perforated and non-perforated Paperpot containers. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Note No. 50. 4 p.
- 51 **Lautenschlager, R.A.** 1993. Diversionary foods and forest regeneration. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Note No. 51. 3 p.
- 52 **Ride, K. and F.W. Bell.** 1995. Overview of forestry applications for the Ford Versatile tractor. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Note No. 52. 8 p.
- 53 **Jayaraman, K. and W.T. Zakrzewski.** 1996. Regression with autocorrelated errors: Application in stem-profile models. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Note No. 53. 8 p.
- 54 **Dey, D.C. and R.P. Guyette.** 1996. Early fire history near Papineau Lake, Ontario. Ont. Min. Nat. Res., Ont. For. Res. Inst., For. Res. Note No. 54. 4 p.
- 55 **Dey, D.C. and R.P. Guyette.** 1996. Early fire history near Seguin Falls, Ontario. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Note No. 55. 4 p.
- 56 **Greifenhagen, S. and G. Halicki-Hayden.** 1997. Assessing conifer seed for fungal pathogens. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Note No. 56. 8 p.
- 57 **Kostyk, B., S. Greifenhagen and F.W. Bell.** 1997. Effects of alternative conifer release treatments on yellowheaded spruce sawfly defoliation. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Note No. 57. 4 p.
- 58 **Noland, T.L., G.H. Mohammed and N.H. Seymour.** 1999. Using the fluorescein diacetate staining method to estimate seed viability of jack pine, black spruce, and white spruce. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Note No. 58. 4 p.
- 59 **Greifenhagen, S. and G. Halicki-Hayden.** 2000. Imidacloprid reduces *Lygus lineolaris* damage to white pine seedlings. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Note No. 59. 8 p.
- 60 **Parker, B. and B. Brown.** 2001. Using fire hose to protect microclimate station electrical cables in forest research. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Note No. 60. 4 p.
- 61 **McPherson, S., S. Strobl and R. Spence.** 2002. Efficacy of the EZJECT lance for releasing red oak from sugar maple competition. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Note No. 61. 4 p.
- 62 **Colombo, S.J. and S. Gellert.** 2002. Frost hardiness testing: An Ontario update. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Note No. 62. 4 p.
- 63 **Parton, J., M. Roddick and M. Woods.** 2003. The carbon budget of Ontario's forests: Phase I: The carbon stocks of Ontario's managed forest lands for 1990 – The monitoring network. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Note No. 63. 4 p.
- 64 **Lu, P., D.G. Joyce and R.W. Sinclair.** 2003. Seed source selection of eastern white pine. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Note No. 64. 4 p.
- 65 **Peng, C., Q. Dang, J. Liu, X. Zhou and J. Chen.** 2003. Quantifying Ontario's forest carbon budgets: I. Developing and testing a dynamic forest carbon budget model for Ontario. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Note No. 65. 4 p.
- 66 **Parker, W.C. and S.J. Colombo.** 2003. Modelling the future forest: Establishing a sound basis for climate change research. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Note No. 66. 4 p.
- 67 **Zakrzewski, W.T. and F. Schneckeburger.** 2006. Stem Data Management System for the Great Lakes Stem Profile Modelling Project, Version 2.0. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Note No. 67. 16 p.
- 68 **Noland, T.L., G. McVey and D. Chapeskie.** 2006. Ice storm and fertilization effects on root starch, sap productivity and sweetness, diameter growth, and tap hole closure in sugar maple stands of eastern Ontario. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Note No. 68. 6 p.
- 69 **McLaughlin, J.A., T. Hsiang, G. Halicki-Hayden and S. Greifenhagen.** 2009. Mortality in southern Ontario red pine plantations: Causes, consequences and management options. Ont. Min. Nat. Resour., Ont. For. Res. Inst., For. Res. Note No. 69. 4 p.

Appendix VI. Climate Change Research Reports

- 01 Wotton, M., K. Logan and R. McAlpine. 2005. Climate change and the future fire environment in Ontario: Fire occurrence and fire management impacts. Ont. Min. Nat. Resour., Appl. Res. Devel. Br., Climate Change Res. Rep. No. CCRR-01. 22 p.
- 002 Boivin, J., J.-N. Candau, J. Chen, S. Colombo and M. Ter-Mikaelian. 2005. The Ontario Ministry of Natural Resources large-scale forest carbon project: A summary. Ont. Min. Nat. Resour., Appl. Res. Devel. Br., Climate Change Res. Rep. No. CCRR-02. 11 p.
- 03 Colombo, S.J., W.C. Parker, N. Luckai, Q. Dang and T. Cai. 2005. The effects of forest management on carbon storage in Ontario's forests. Ont. Min. Nat. Resour., Appl. Res. Devel. Br., Climate Change Res. Rep. No. CCRR-03. 126 p.
- 04 Hunt, L.M. and J. Moore. 2006. The potential impacts of climate change on recreational fishing in Northern Ontario. Ont. Min. Nat. Resour., Appl. Res. Devel. Br., Climate Change Res. Rep. No. CCRR-04. 32 p.
- 05 Colombo, S.J., D.W. McKenney, K.M. Lawrence and P.A. Gray. 2007. Climate change projections for Ontario: Practical information for policymakers and planners. Ont. Min. Nat. Resour., Appl. Res. Devel. Br., Climate Change Res. Rep. No. CCRR-05. 37 p.
- 06 Lemieux, C.J., D.J. Scott, P.A. Gray and R.G. Davis. 2007. Climate change and Ontario's provincial parks: towards an adaptation strategy. Ont. Min. Nat. Resour., Appl. Res. Devel. Br., Climate Change Res. Rep. No. CCRR-06. 82 p.
- 07 Carter, T., W. Gunter, M. Lazorek and R. Craig. 2007. Geological sequestration of carbon dioxide: A technology review and analysis of opportunities in Ontario. Ont. Min. Nat. Resour., Appl. Res. Devel. Br., Climate Change Res. Rep. No. CCRR-07. 24 p.
- 08 Browne, S.A. and L.M. Hunt. 2007. Climate change and nature-based tourism, outdoor recreation, and forestry in Ontario: potential effects and adaptation strategies. Ont. Min. Nat. Resour., Appl. Res. Devel. Br., Climate Change Res. Rep. No. CCRR-08. 50 p.
- 09 Varrin, R., J. Bowman and P.A. Gray. 2007. The known and potential effects of climate change on biodiversity in Ontario's terrestrial ecosystems: case studies and recommendations for adaptation. Ont. Min. Nat. Resour., Appl. Res. Devel. Br., Climate Change Res. Rep. No. CCRR-09. 34 p + append.
- 10 *Climate Change and Renewable Energy in Ontario: Mitigation and Adaptation. (in revision)*
- 11 Dove-Thompson, D., C. Lewis, P.A. Gray, C. Chu and W. Dunlop. 2011. A summary of the effects of climate change on Ontario's aquatic ecosystems. Ont. Min. Nat. Resour., Appl. Res. Devel. Br., Climate Change Res. Rep. No. CCRR-11. 56 p.
- 12 Colombo, S.J. 2008. Ontario's forests and forestry in a changing climate. Ont. Min. Nat. Resour., Appl. Res. Devel. Br., Climate Change Res. Rep. No. CCRR-12. 21 p.
- 13 Candau, J.-N. and R. Fleming. 2008. Forecasting the response to climate change of the major natural biotic disturbance regime in Ontario's forests: the spruce budworm. Ont. Min. Nat. Resour., Appl. Res. Devel. Br., Climate Change Res. Rep. No. CCRR-13. 14 p.
- 14 Minns, C.K., B.J. Shuter and J.L. McDermid. 2009. Regional projections of climate change effects on Ontario lake trout (*Salvelinus namaycush*) populations. Ont. Min. Nat. Resour., Appl. Res. Devel. Br., Climate Change Res. Rep. No. CCRR-14. 11 p.
- 15 Subedi, N., M. Sharma and J. Parton. 2009. An evaluation of site index models for young black spruce and jack pine plantations in a changing climate. Ont. Min. Nat. Resour., Appl. Res. Devel. Br., Climate Change Res. Rep. No. CCRR-15. 16 p.
- 16 McKenney, D.W., J.H. Pedlar, K. Lawrence, P.A. Gray, S.J. Colombo and W.J. Crins. 2010. Current and projected future climatic conditions for ecoregions and selected natural heritage areas in Ontario. Ont. Min. Nat. Resour., Appl. Res. Devel. Br., Climate Change Res. Rep. No. CCRR-16. 24 p.
- 17 Hasnain, S.S., C.K. Minns and B.J. Shuter. 2010. Key ecological temperature metrics for Canadian freshwater fishes. Ont. Min. Nat. Resour., Appl. Res. Devel. Br., Climate Change Res. Rep. No. CCRR-17. 42 p.

Appendix VII. Climate Change Research Information Notes

- 01 Warner, B.G., J.C. Davies, A. Jano, R. Aravena, and E. Dowsett. 2003. Carbon storage in Ontario's wetlands. Ont. Min. Nat. Resour., Appl. Res. Devel. Br., Climate Change Res. Info. Note CCRN-01. 4 p.
- 02 **Colombo, S.J.** 2006. How OMNR staff perceive risks related to climate change and forests. Ont. Min. Nat. Resour., Appl. Res. Devel. Br., Climate Change Res. Info. Note CCRN-02. 8 p.
- 03 Obbard, M.E., M.R.L. Cattet, T. Moody, L.R. Walton, D. Potter, J. Inglis and C. Chenier. 2006. Temporal trends in the body condition of southern Hudson Bay polar bears. Ont. Min. Nat. Resour., Appl. Res. Devel. Br., Climate Change Res. Info. Note CCRN-03. 8 p.
- 04 Jackson, B. 2007. Potential effects of climate change on lake trout in Atikokan Area. Ont. Min. Nat. Resour., Appl. Res. Devel. Br., Climate Change Res. Info. Note CCRN-04. 4 p.
- 05 Bird, N.D. and E. Boysen. 2006. The carbon sequestration potential from afforestation in Ontario. Ont. Min. Nat. Resour., Appl. Res. Devel. Br., Climate Change Res. Info. Note CCRN-05. 4 p.
- 06 **Colombo, S.J., J. Chen and M.T. Ter-Mikaelian.** 2006. Carbon storage in Ontario's forests, 2000-2100. Ont. Min. Nat. Resour., Appl. Res. Devel. Br., Climate Change Res. Info. Note CCRN-06. 8 p.
- 07 Trumpickas, J., B.J. Shuter and C.K. Minns. 2008. Potential changes in future surface water temperatures in the Ontario Great Lakes as a result of climate change. Ont. Min. Nat. Resour., Appl. Res. Devel. Br., Climate Change Res. Info. Note CCRN-07. 8 p.
- 08 **Colombo, S.J., B. Boysen, K. Brosemer, A. Foley and A. Obenchain.** 2008. Managing tree seed in an uncertain climate: Conference summary. Ont. Min. Nat. Resour., Appl. Res. Devel. Br., Climate Change Res. Info. Note CCRN-08. 8 p.
- 09 Gleeson, J., G. Nielsen and **W.C. Parker.** 2009. Carbon offsets from afforestation and the potential for landowner participation in Ontario. Ont. Min. Nat. Resour., Appl. Res. Devel. Br., Climate Change Res. Info. Note CCRN-09. 8 p.
- 10 **Parker, W.C., G. Nielsen, J. Gleeson and R. Keen.** 2009. Forecasting carbon storage and carbon dioxide offsets for southern Ontario afforestation projects: The 50 Million Tree Planting Program. Ont. Min. Nat. Resour., Appl. Res. Devel. Br., Climate Change Res. Info. Note CCRN-10. 8 p.
- 11 Gleeson, J. and D. La Croix-McDougall. 2009. MNR's carbon footprint: An assessment for three business areas. Ont. Min. Nat. Resour., Appl. Res. Devel. Br., Climate Change Res. Info. Note CCRN-11. 4 p.

Appendix VIII. Science Development and Transfer Series Reports

- 001 **MacDonald, G.B.**, J. Fraser and P. Gray. (eds.). 1999. Adaptive management forum: Linking management and science to achieve ecological sustainability. Ont. Min. Nat. Resour., Sault Ste. Marie, ON. Sci. Devel. Transf. Ser. No. 001. 58 p.
- 002 **Hayden, J.**, E. Boysen, M. Woods and **J. Rice**. 1999. Making cents out of forest inventories: A guide for small woodlot owners. Ont. Min. Nat. Resour., Sault Ste. Marie, ON. Sci. Devel. Transf. Ser. No. 002. 32 p. + append.
- 003 **Bell, F.W.**, D.G. Pitt, M. Irvine, **W.C. Parker**, **L.J. Buse**, N. Stocker, W.D. Towill, H. Chen, F. Pinto, K. Brown, **D. DeYoe**, T. McDonough, G. Smith and M. Weber. 2000. Intensive forest management in Ontario: Summary of a 1999 science workshop. Ont. Min. Nat. Resour., Ont. For. Res. Inst., Sault Ste. Marie, ON. Sci. Devel. Transf. Ser. No. 003. 86 p.
- 004 Latremouille, C., **W.C. Parker**, S. McPherson, F. Pinto, B. Fox and L. McKinnon. 2008. Ecology and management of white pine in the Lake Abitibi (3E) and Lake Temagami (4E) ecoregions of Ontario. Ont. Min. Nat. Resour., Ont. For. Res. Inst., Sault Ste. Marie, ON and Northeast Sci. Inf. Unit, South Porcupine, ON. Sci. Devel. Transf. Ser. . No. 004. 64 p. + append.

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